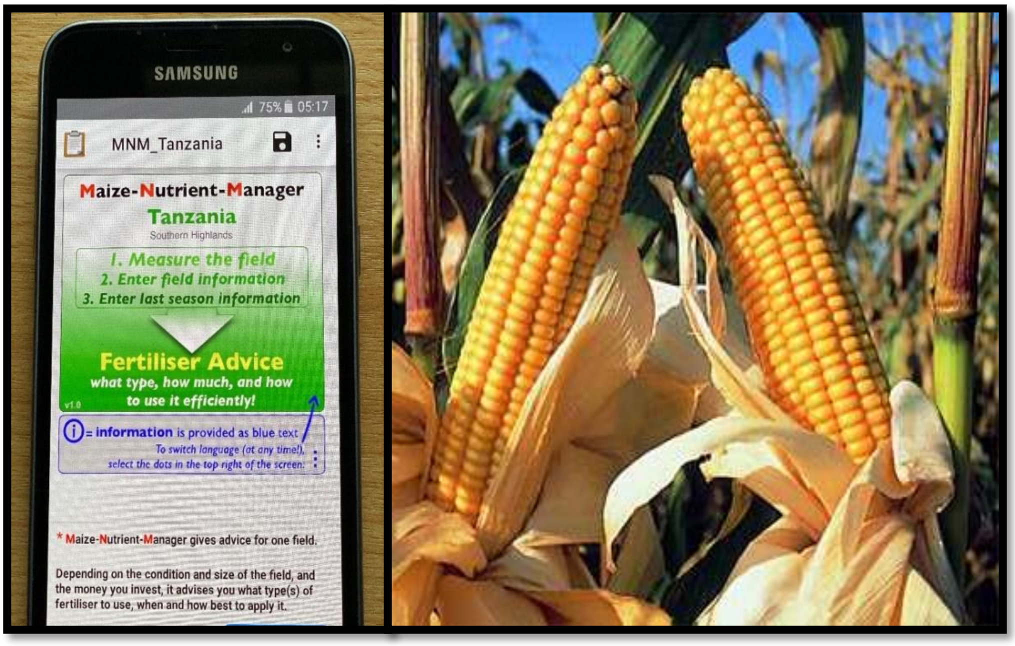
An agronomic impact evaluation of the Maize-Nutrient- Manager (MNM) mobile phone application in the Southern Highlands of Tanzania

MSc thesis Plant Production Systems



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MSc Thesis Plant Production Systems

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Acronyms and abbreviations

ANOVA	Analysis of Variance
CAN	Calcium Ammonium Nitrate
DAP	Diammonium Phosphate
CIMMYT	The international Maise and Wheat Improvement Center
FAO	Food and Agriculture Organizations of the United Nations
FUE	Fertiliser Use efficiency
ICRISAT	The International Crop Research Institute for the Semi-Arid Tropics
N	Nitrogen
P	Phosphorus
K	Potassium
MNM	Maise-Nutrient-Manager mobile phone application
N-AE	Nitrogen Agronomic Use Efficiency
SSA	Sub-Saharan Africa
TPB	The Theory of Planned Behavior

Abstract

Fertiliser intensification is often perceived as an option for improving food security in SSA, where low inherent soil fertility and fertiliser use have led to soil mining and low yields of important staple crops such as maise. Intensifying fertiliser use in Africa may have negative impacts on the environment and might not be economically viable. Therefore, a focus on improving fertiliser use efficiency (FUE) can be an alternative that can help to minimise nutrient losses to the environment, while at the same time increasing maise grain yields. However, one major constraint in African smallholder farming systems is a lack of fertiliser recommendations that are tailored to specific farmer and field conditions.

This study evaluates the agronomic impact of a field-specific fertiliser advisory tool on FUE. The Maize-Nutrient-Manager (MNM) tool is a mobile phone application that was used by extension workers advising maise-growing smallholder farmers in the Southern Highlands of Tanzania in the 2019/20 maise season. To determine the impact of MNM advice on FUE, the Agronomic Efficiency of Nitrogen (N-AE) was used as an indicator. Using telephone-based interviews, the impact of MNM was evaluated for a subset of farmers (35 control and 40 MNM intervention). Results show that MNM advice improved N-AE in this first year of field-specific advice provision (n=40), from 8.31 in the 2018/19 to 27.39 additional kg grain yield/kg N applied in 2019/20 season. Consequently, the MNM users – with less fertiliser application - reached the same maise grain yield on average as the control group.

These results indicate that decision support tools on fertiliser management - right timing of top dressing fertilisers application and a balanced application rate of N and P - can contribute to improved FUE in the maise-dominated farming systems of the Southern Highlands of Tanzania. Further research may identify more management practices in the area that can improve field-specific fertiliser advisory.

1.Introduction

The demand for cereals, including maise, in Sub-Saharan Africa (SSA), will triple by 2050 due to rapid population growth (Van Ittersum et al.,2016). For example, the demand for maise in Tanzania by 2050 will be 17.3 Mt y^{-1} from the current demand of around 5.5 Mt y^{-1} (Ten Berge et al.,2019). Much of the maise production in SSA is done by smallholder farmers in rainfed environments (Deichmann et al., 2016). This production is both for household consumption and sale. However, its cultivation is generally characterised by low yields (Cairns et al., 2013). The low yields are often the result of low soil fertility, pests, and diseases, weeds, as well as low and inappropriate use of inputs such as fertilisers (Sanchez, 2002). To keep pace with the increase in food demand due to a growing population in SSA, yields of maise as one of the major staple crops will need to increase.

Adoption of best agronomic practices by farmers, including efficient use of fertilisers and pest and diseases management are likely to improve maise yields (Ichami et al., 2018). The study by Ten Berge et al. (2019) showed that an increase in N, P and K inputs to maise production systems of SSA would also increase yield. Nevertheless, that increase in nutrients must be coupled with strategies to reduce possible nutrient losses to the environment. Fertiliser use efficiency (FUE) can be a key entry point to minimise nutrient losses while at the same time, increase maise grain yield in SSA. If FUE is increased, more yield can be obtained per unit of fertiliser applied with reduced nutrient losses (Rietra et al. 2017). However, one major constraint to fertiliser use efficiency in SSA is a lack of fertiliser recommendations tailored to specific farmer and field conditions (Wortmann et al., 2018). Usually, blanket fertiliser recommendations are more common. A blanket fertiliser recommendation is a general recommendation (type and amount of fertiliser) usually given at regional level, for example, an administrative district (Ichami et al., 2019). As such, these recommendations often fail to account for the diversity of smallholder situations (Deichmann et al.,2016). The diversity in nutrient management practices, soil fertility, cropping history, and the financial status of the farmer requires advice to be adapted to field and farmer conditions such as fertiliser availability and others.

Improving fertiliser recommendations, therefore, is likely to increase fertiliser use efficiency (FUE) in African smallholders' maise fields (Ichami et al., 2019). FUE can be measured or assessed by agronomic nitrogen use efficiency (N-AE) as one of the indicators for improved FUE (Dobberman, 2007). N-AE is defined as the increase in maise grain yield per unit of fertiliser N applied (Vanlauwe et al., 2011). This study investigated the impact of field-specific fertiliser advice on FUE. The fertiliser advice was generated by the Maize Nutrient Manager (MNM) mobile phone application, a digital tool used by maise growing farmers in the Southern Highlands region of Tanzania for the 2019/20 season.

1.1 Maise nutrient management practices by smallholder farmers in the Southern Highlands region of Tanzania.

The smallholder farmers engaged in this study usually have maise fields of two hectares or smaller (Kilakila,2020). They often practice crop rotation and intercropping to improve maise productivity. N-fixing legumes (groundnuts and beans) are the most used crops in rotation with maise and form an alternative source of nitrogen (Kilakila, 2020). Farmers with access to manure, either from their own livestock or bought, may also apply this in their maise fields, although not always on an annual basis (Kilakila, 2020). Use of inorganic fertilisers in maise is also a common practice. With regard to inorganic fertiliser use, the blanket fertiliser recommendation in the region is 120kg/ha of **N** and 20 kg/ha of **P**, and no advice for K(Andersson et al., 2020). However, quantities applied to vary greatly, as do soil fertility and farm management practices within the region. More characteristics of the farmers and the study area are provided in chapter two of this thesis.

1.2 MNM: A digital tool for field-specific fertiliser advice for maise

MNM was designed by the department of plant production systems at Wageningen University, in collaboration with CIMMYT. The purpose of the designed digital tool was to improve fertiliser (management) advice provided to maise growing farmers in the Southern Highlands of Tanzania. Thus, the MNM generates advice tailored to farmers' field conditions, fertiliser availability and the farmer preferred investment level, in contrast to the current standardised fertiliser recommendation, which barely suits their local conditions. The MNM advice focused on the adoption of four best fertiliser management practices for improving fertiliser use efficiency (Andersson et al., 2020):

1. The right type of fertiliser

Farmers were recommended to use P fertiliser such as DAP at planting or at emergence in case of ''dry-planting''. Dry-planting means seeding before the rains. At top-dressing fertiliser application, farmers were advised to use N -fertiliser such as Urea.

2. The right balance of nutrient N and P

Based on the cash or in-kind amount of fertiliser investment the farmer is willing to put in, MNM advises the amounts of fertiliser to use, based on a standard balanced nutrient ratio of N:P (6:1). Potassium (K) was not included in the ratio, as the soils in the Southern Highlands are considered not K-deficient. Since DAP and Urea are the cheapest and widely available sources of P and N respectively, the MNM investment-based advice generates initial advice in kg DAP and Urea with a balanced ratio of N:P. However, if a farmer observed P-deficiency in his/her maise in the previous season, the MNM generates advice with a lowered N:P ratio. For the case of K-deficiency in the last season, the MNM advises the use of NPK basal fertiliser, plus a balanced N:P ratio.

3. Right time

The application of top dressing fertiliser (N) was recommended at 5-6 developed leaves. If more than 25kg of top-dressing fertiliser was used then, the farmer was advised to split the application, with the first half at 5-6 leaves and the second split at later stages before flowering.

4. Right place

Placement method was recommended against broadcasting for basal of fertiliser application.

The MNM also collected data at the field level, which is often not readily available to researchers and other stakeholders in the agriculture sector. The tool was run as a pilot in 2019 to generate advices for about 1000 farmers in the Mbozi and Momba districts in the Southern Highlands of Tanzania for the 2019/20 season.

1.3 Aim of this study: An agronomic impact evaluation of MNM

Impact evaluation of intervention provides evidence of whether the intended goals of that intervention were achieved (Gertler et al., 2016). Such evidence often guides future funding and intervention program design and decision making (Mayne, 2001). The impact can be measured by looking at the achievement of the initial objectives of the intervention or by looking at the emerging outcomes that result from a process of change (Glover et al.,2019).

This study’s aim was to evaluate the agronomic impact of the MNM and to understand better the drivers of observed changes in farmers' fertiliser use practices. The agronomic impact of the MNM is defined as a change in fertiliser use practices towards improved fertiliser use efficiency and yield. To determine the agronomic impact of MNM, two approaches were adopted. First, an econometric approach to impact evaluation using the Difference in Difference (DD) method and N-AE as an indicator for fertiliser use efficiency. Second, the socio-technological impact approach using the theory of planned behaviour (TPB) and the 'rethinking adoption' framework developed by Glover et al. (2019). The TPB theory (Ajzen, 1991) and the ’rethinking adoption’ framework were adopted to complement the DD method.

Outcomes of this study contributed to the understanding of the process of change, advice uptake, and the potential impact fo the MNM intervention in smallholder farming systems in the Southern Highlands of Tanzania. This study’s findings were also key to improving MNM tool for future intervention design and implementation.

1.4.MNM impact evaluation: two approaches

First, the DD method was employed to quantify the change in fertiliser use practises and yield following the provision of MNM advice, and to see if this change could be attributed to MNM. Second, the 'rethinking adoption' framework developed by Glover et al. (2019) and the TPB theory further investigated this, focusing on the drivers of change in farmers' fertiliser (management) practices and yield. The second approach investigated how and why a change in fertiliser use practices and yield occurred between the 2018/19 and 2019/20 maise growing seasons.

1.4.1 The Difference-in-difference (DD): a Counterfactual Impact Evaluation approach

The DD method is an econometric method for impact evaluation which relates the start situation (baseline) and outcomes of an intervention by comparing two groups of participants involved in the process of an ongoing change (Gertler et al., 2016). Amongst the two groups is a control group (no intervention) and an intervention group. The change in the outcome that takes place in the control group is taken as what would have happened to the intervention group in the absence of the intervention (White, 2016). The change observed in the control group is called counterfactual. Therefore, the impact of the intervention is measured as the change in the outcome observed in the intervention group minus the change observed in the control group. In this study, the control group comprises of farmers who did not receive the MNM intervention. The intervention group consists of farmers who received MNM fertiliser advice in the 2019/20 season.

The following are the advantage of the DD method (White et al., 2017)

- DD removes any difference in the indicator between intervention and control groups which was present at baseline, and this is useful because these differences are not a result of the intervention.
- It also removes the effects of general trends affecting both groups, E.g. flood, as it was the case this season.

The DD method of impact evaluation is not without its limitations. First, the DD method fails to explain how and why changes in behaviour occurred after the intervention (White, 2009). Second, it also assumes that the observed changes are only due to the intervention which may not be the case in complex interventions like MNM (Glover et al. 2019)

In order to countercheck the DD method, this study adopted two additional theoretical and methodological approaches, as its main aim was to better understand the drivers of the observed changes in farmers' fertiliser use practices in the time of MNM intervention (how and why). First, the theory of planned behaviour (TPB) problematises behavioural change and provides a framework to investigate the attitudes and intentions of individual farmers' that structure their responses (behaviour) to the intervention (Ajzen, 1991). Second, the 'rethinking adoption' framework developed by Glover et al. (2019) problematises the simplistic notion of technology adoption as a binary process (yes/no) and proposes a wider perspective on the process of change, investigating the encounters, dispositions and responses that drive the change following an intervention.

1.4.2 Theory of Planned Behaviour (TPB)

TPB is the theory that helps to understand and predict the intended behaviour in response to intervention (Ajzen, 1991). The expected behaviour in the MNM intervention was the change in fertiliser practice following MNM fertiliser advice. Central to the TPB is the intention of the individual in the target population to perform the expected behaviour. The intention in MNM intervention begun with a change in perception of the farmer towards the adoption of best fertiliser management practices. Then putting MNM fertiliser advice into practice.

The TPB theory guides the structure of the interview with farmers to understand farmers' intention and perception towards MNM use. It also guides the researcher to investigates possible risks and unintended benefits of the MNM intervention. The TPB is comprised of the following five constructs (Figure 1) that collectively represent a person's actual control over his/her behaviour (Ajzen, 1991):

1. Attitudes - This refers to the degree to which a person has a favourable or unfavourable evaluation of the behaviour of interest. It entails a consideration of the outcomes of performing the behaviour.
2. Behavioural intention - This refers to the motivational factors that influence a given behaviour where the stronger the intention to perform the behaviour, the more likely the behaviour will be performed.
3. Subjective norms - This refers to the belief about whether most people approve or disapprove of the behaviour. It relates to a person's beliefs about whether peers and people of importance to the person think he or she should engage in the behaviour.
4. Behaviour - An individual's observable response in a given situation with respect to a given target. Ajzen (1991) said that behaviour is a function of compatible intentions and perceptions of behavioural control. The perceived behavioural control is expected to moderate the effect of intention on behaviour, such that a favourable intention produces the behaviour only when perceived behavioural control is strong.
5. Perceived behavioural control - This refers to a person's perception of the ease or difficulty of performing the behaviour of interest. Perceived behavioural control varies across situations and actions, which results in a person having varying perceptions of behavioural control

depending on the situation. This construct of the theory was added later and created the shift from the Theory of Reasoned Action to the Theory of Planned Behavior.

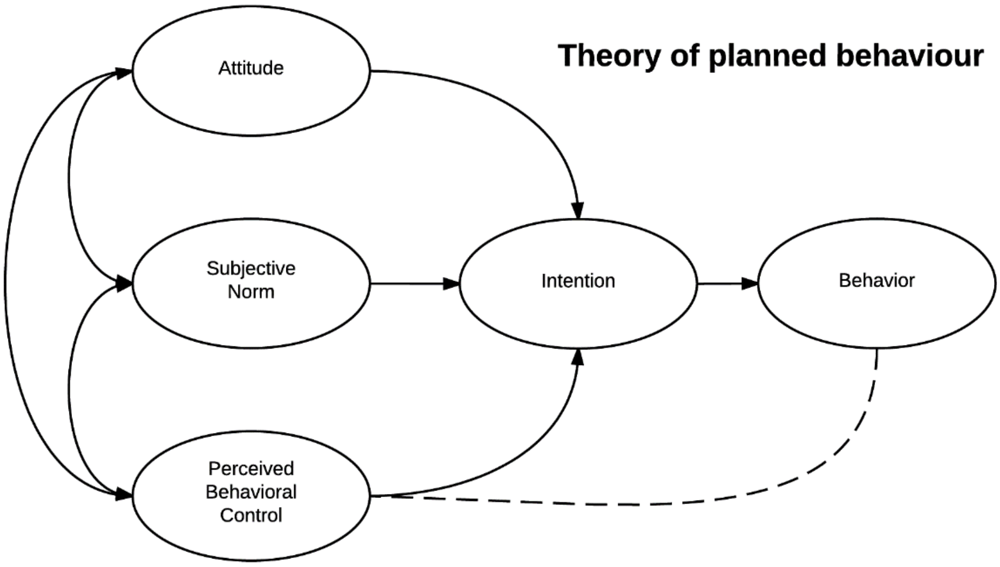


Figure 1. Theory of Planned Behaviour (TPB) (Ajzen, 1991)

1.4.3 Rethinking Adoption Framework by Glover et al. (2019): understanding socio-technical change of an intervention

Rethinking Adoption Framework does not start at the level of the individual decision-maker but focuses on understanding processes of socio-technological change. It recognises the dynamic and complex socio-technical changes observed as the process of technology adoption unfolds in the targeted population (Glover et al., 2019). When adoption is used as the principal indicator of success or failure, "there is a real risk of overlooking the wider positive or negative impact of technological change, including unintended benefits, costs and risks" (Glover et al.,2019, p.4). Therefore, focusing on the processes of technological change happening at the level of technology users (in this case the MNM farmers) opens the possibility to investigate both unintended and anticipated impacts of MNM intervention (Glover et al.,2019).

The Rethinking Adoption Framework guides the construction of the interview's questionnaires for this study. Moreover, in the discussion chapter of this report, it provides a framework for the exploration of unanticipated consequences of MNM use and its implications.

The Rethinking adoption framework analyses the change process by taking the (MNM) intervention apart in propositions (inputs), encounters between interveners and recipients (an 'emergent input'), both their dispositions and recipients' responses. Glover et al. (2019) see the change that occurred as the sum of these different elements (or multiple 'inputs') that constitute the intervention. These four elements are both social and technical and together are coined as the socio-technical change of an intervention. The four aspects of the ‘Rethinking Adoption Framework’ in the context of the MNM intervention, are discussed below:

Proposition: MNM advice

The Glover et al. (2019) framework define a proposition as a new technological idea encountered by targeted or any potential user of that technology. In this case, the maise growing farmers in the Southern Highlands of Tanzania were introduced to the use of MNM fertiliser advice.

Encounters: agricultural extensionist-MNM farmers

Encounters "constitutes of most public and private agricultural extension activities. Farmer meetings, training events, demonstration trials, farm visits, field days, and field schools. Encounters can also occur spontaneously and without formal direction, such as when a farmer sees a new technology being practised by a neighbour or relative or hears about it..." (Glover et al.,2019, p.7). In this study, three encounters were investigated: the first encounter was that between the extension worker and the MNM group in the 2019/20 season. The second and third encounters were that of the researcher of this study with the control group in the 2018/19 and 2019/20 seasons, respectively.

Dispositions

Dispositions are defined as an inclination to act in a particular way. This inclination is structured by (social) circumstances (Glover et al. 2019). In the MNM intervention, farmers' dispositions towards MNM advice were investigated.

Responses: Farmers' responses to MNM fertiliser advice

Farmers in the Southern Highlands of Tanzania responded -in different ways towards MNM fertiliser advice. These ways could be different from those anticipated or intended by the designers of the MNM. Glover et al. et al. (2019) suggest that the way in which farmers responded to MNM fertiliser advice was shaped by their specific socio-economic and farming circumstances. Nevertheless, such responses are also shaped by the (quality of) the encounters between farmers-and extensionists and the features of the MNM application.

1.5 Research questions

The DD, the TPB and the Rethinking Adoption Framework helped to answer the three research questions of this study outlined below. To evaluate the agronomic impact of the MNM (study aim), it is first necessary to analyse if and how farmers' fertiliser use practices and yields have changed from the 2018/19 to the 2019/20 season (the pattern of change), and whether this is different for those who received MNM advice and those who did not (the control group). Therefore, **the first research**

question focused on comparing the fertiliser use practices and achieved yields of the intervention group and the control group before and after the MNM intervention, using the DD method. **Research question two** focused on the effect of the pattern of change in fertiliser use practices on fertiliser use efficiency. **Research question three** focused on understanding the drivers of change (the why and how questions) and builds on the TPB and Glover's framework and explanations provided by farmers in telephone interviews. The three research questions are outlined below:

RQ 1: *How did fertiliser use practices and yields differ between control and intervention groups in the 2018/2019 and 2019/20 seasons, regarding:*

i) Fertiliser types used (N and P-fertilisers)
ii) Quantities applied (N and Pkg ha^{-1})
iii) Timing and method of application for both basal and top-dressing
iv) Yield

Hypothesis 1*:* the two groups were on average similar in fertiliser use practices and maise grain yield.

Sub-questions:

1.1 Are the control and intervention groups **similar** in their fertiliser use practices and achieved yields before the MNM intervention?
1.2 Are the control and MNM groups **differ** in their fertiliser use practices and achieved yields after the MNM intervention?
1.3 What is the difference in fertiliser use practices and achieved yields between 2019/20 and 2018/19 for the control and intervention groups?

RQ 2: What are the effects of change in fertiliser use practices, due to the MNM intervention, on fertiliser use efficiency?

Hypothesis 2**:** farmers with an MNM intervention had a larger increase in N-AE between the two seasons than farmers without the MNM intervention.

RQ 3: What do farmers' see are the drivers of change in fertiliser use practices and yield, how and why do they occur?

Hypothesis 3**:** MNM was not the only driver of change in fertiliser use practices and obtained yield between seasons.

The rest of this thesis is organised into four chapters. Chapter 2 presents the material and methods used throughout the study. Chapter 3 presents the results of the study. Chapter 4 and 5 the final, offers a discussion on findings and draws some important conclusions and recommendations.

2. Material and Methods

2.1 Study area: the social and agroecological characteristics

The study was conducted in the Mbozi and Momba districts (Songwe region) of the Southern Highlands of Tanzania, which borders Zambia and Malawi (Figure 1). Songwe region is located between latitude 7^0 to 11.5^0 S and longitude 30^0 and 38^0 E and at 1261m above sea level. The tropical climate of the region is characterised by a unimodal rainfall pattern with an average annual rainfall of 1577 mm occurring from November to May. The average annual temperature is 20.8^0C, with a maximum temperature of 22.8^0C in November. July is the coldest month, with a temperature of 18.3^0C (Climate-data.org, 2020). The soils of the Southern Highlands region of Tanzania are diverse and cover a broad range of soil types. The report of Soil Fertility of Tanzania by Mowo et al. (1993) mentions the following classes to be dominant in the region; a high altitude plateau in a mountainous area, with medium to heavy textured clayey soils with low to moderate inherent fertility.

The district of Mbozi, where much of the fieldwork was undertaken, covers an area of 3858 km^2 with a population of 446, 339 at a density of 115.7/km^2. About 82.6% of the population is living in rural areas where agriculture is the main occupation (City population, 2020). The majority of rural inhabitants engage in crop farming or mixed farming where they keep livestock, including large and small ruminants and chickens. The main crops that seem to be a source of income in the region are maise, coffee, banana, and beans. Maise and beans are a source of both income and food.

Figure 2 shows the map of Africa locating Tanzania and extrapolated region of Songwe showing the two study areas of Mbozi and Momba districts. Within Mbozi and Momba, the map shows the wards of villages where the fieldwork was conducted between September 2019 to February 2020.

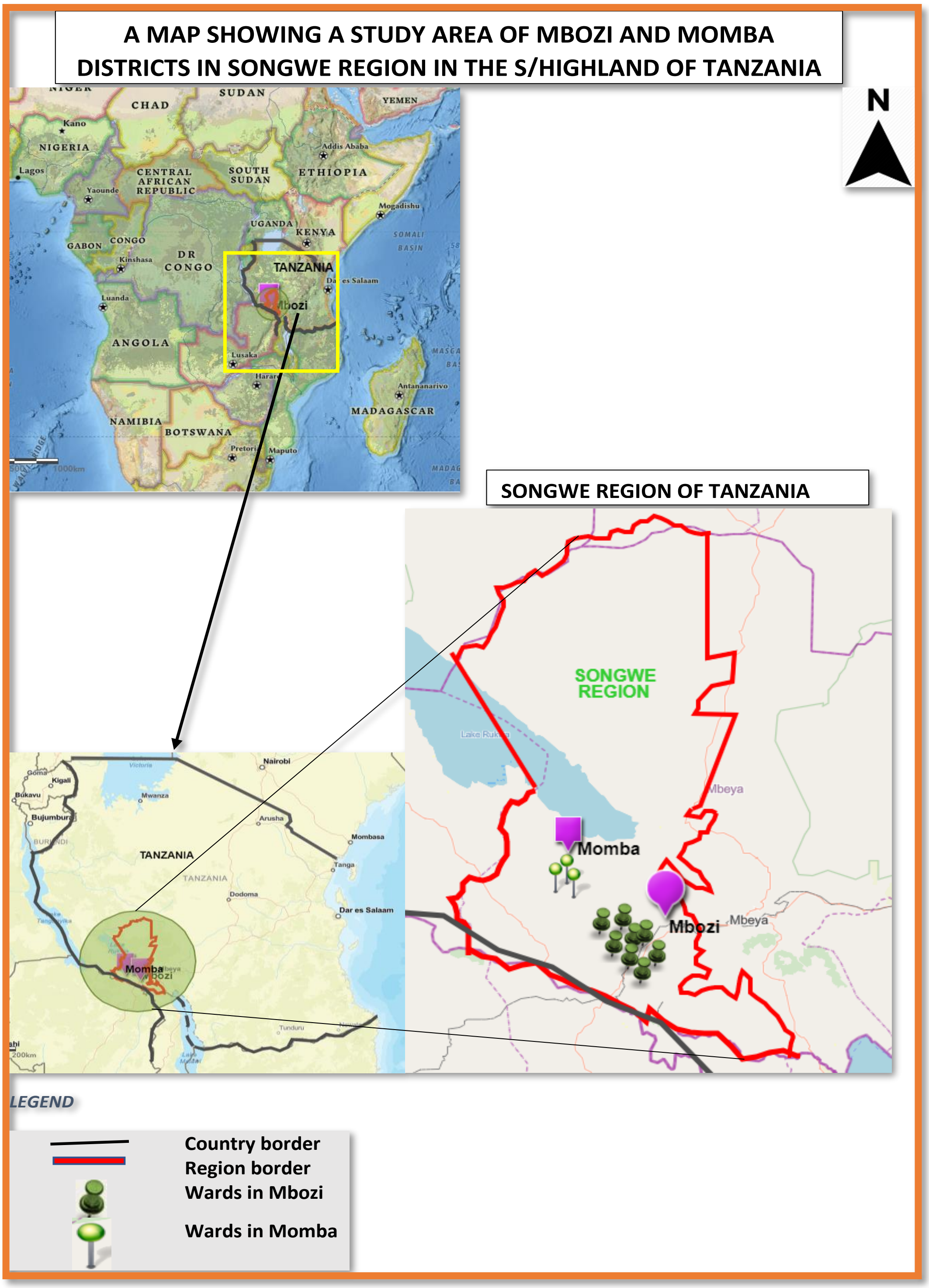


Figure 2. A map of Tanzania with an extrapolated region of Songwe showing the study areas of Mbozi and Momba districts. (Adapted from Kilakila, 2020)

2.3 Study design and sampling strategy

This study adopted a quasi-experimental design, which involved the construction of a control and intervention group in the study population and comparison of the matching variables between the groups based on the researcher's judgment about what variables were important (Rogers, 2014). The studied population composed of two groups of maise growing smallholder farmers. The first group of farmers was the control with no intervention. The control group was interviewed in September to November 2019 to understand maise growing and fertiliser use practices better. The findings were partially used to develop MNM. The second group (intervention group) received MNM advice in November and December 2019. Data collected from these two groups on the 2018/19 season formed the baseline while data collected through written forms and through phone interviews (by skype from the Netherlands) on the 2019/20 season formed the end line data for this study (table 1)

2.3.1 Selection of farmers for the data collection on the 2018/19 maise growing season

Control group (n=102)

Farmers were randomly selected by the researcher with the help of agricultural extension workers residing in the study area. Any willing farmer who had grown maise in the 2018/19 season and lived in the area was eligible to participate in the survey. In the field, the researcher and extension worker visited farmers without appointments, as to avoid any prior influence on the results. Then farmers were asked for consent to participate in the survey.

Intervention group (n= ±1,000)

A similar strategy was used to select farmers for the intervention group, except that this time, (1) farmers were selected by extension workers trained in the use of the MNM mobile phone application (the extension workers were selected based on their experience with smartphones), and; (2) only farmers who were planning to grow maise in the 2019/20 season were selected. For the purpose of this study, 307 farmers from a total of ±1000 who grew maise consecutively in 2018/19 and 2019/20 were selected for MNM impact evaluation.

2.3.2 Selection of farmers for the data collection on the 2019/20 maise growing season

From July to August 2020, which marked the end of 2019/20 maise growing season, farmers from the intervention group were engaged in evaluating the impact of MNM intervention through telephone interviews (originally planned as farm visits, phone interviews had to be done instead, due to COVID-19 induced restrictions on travel). These interviews focused on investigating the pattern of change in fertiliser use practices and achieved yield between the 2018/19 and 2019/20 seasons. The interviews also investigated what drove that pattern of change. To achieve this, both quantitative and qualitative data on farmers' perspectives on the pattern of change and its drivers were collected (Table 1).

During the telephone interviews (which were done through Skype), 90 farmers of the control group were contacted but not fully interviewed; only 35 were valid. About 60 farmers of the MNM group were contacted but also not fully interviewed; only 40 phone interviews were valid. The validity was based on the selection criteria outlined below. Thus 35 farmers from the control and 40 from the intervention group comprised the endline data for this study. The following criteria guided the selection of farmers from within the original samples of 102 and 307 farmers of the control and MNM intervention groups, respectively:

Sample from the control group (n=35)

1. To minimise the spill-over effects of the MNM intervention, the control group composed of farmers who had not received MNM advice from any other farmer or extension worker.
2. All selected farmers cultivated maise on the same measured field area in the season of 2018/2019 and 2019/20 seasons (i.e. they did not practice crop rotation);
3. the selected farmers never received any inorganic fertiliser advice between the 2018/19 and 2019/20 seasons (farmers were asked during the interview)

Sample from MNM intervention group (n=40)

1. The selected farmers cultivated maise on the measured field area in both the 2018/2019 and 2019/20 seasons
2. The interviewed MNM farmers had received MNM advice and filled-out earlier distributed farm management record forms for the 2019/20 season (Appendix 3)
3. The selected MNM farmers managed to keep records of their farming management practices, including that of fertiliser use for the 2019/20 season.

Table 1: Sample size, data collected on the two maise growing seasons (2018/19 and 2019/20). Methods employed for data collection in 2019 before the MNM intervention and in 2020, after the intervention.

Sample	Data collected	Methods for data collection	When
Control (n=102)	Fertiliser use practices and yield for 2018/19 season.	Survey	2019
Intervention (n=307)		MNM mobile application	
Control (n=35)	Fertiliser use practices and yield for 2019/20 season	MNM app, Skype-enabled telephone interview	2020
Intervention (n=40)			

2.4 Data collection through survey and the MNM mobile phone application

2.4.1 The survey

The control group was surveyed in September 2019 to investigate maise farmers' nutrient management practices (types, quantity, and timing of basal and top dressing fertiliser) in the 2018/19 season. The survey was conducted by the researcher of this study during an internship assignment with the International Maize and Wheat Improvement Centre (see: Andersson et al. 2020).

The electronic farmer survey (on a tablet) focused on the farmers' nutrient management practices on one of his/her maise fields. Questions about weeding practices, pest and disease management, planting density and time, fertiliser use and harvest were asked. In the situation where a farmer had more than one maise field, only one field was selected based on the farmers' preference: distance from the homestead, the biggest maise field, the field on which most fertilisers were used, the highest/lowest yielding field, or for another reason. The preferences were recorded for each interviewed farmer. The area of the selected maise field was measured with the help of Global Positioning System (GPS) services by using the MNM mobile phone application.

2.4.2 The MNM mobile phone application

The intervention group was provided with MNM advice for the 2019/20 season. The MNM tool also collected data on field management practices for the maise season of 2018/19, similar to the data collected through the survey. Thirty (30) selected and trained agricultural extension workers of Mbozi and Momba districts used the MNM for both advice provision and data collection.

Agricultural extension workers received a one-day training on the use of the MNM application a few weeks before going out to the field to advise maise growing farmers. The training was conducted by

Dr Jens Andersson, the MNM project supervisor, with the assistance of the researcher of this study. During the training extension workers were asked not to provide MNM advice to farmers who were in the control group. At the end of the MNM intervention, it was evident that extension workers did not provide MNM advice to the control group. This was checked through names and returned advice forms that were only provided to the intervention group.

2.4.3 Data collection through farmer's telephone interview

Data collected in the 2019/20 season formed the end line data for the impact evaluation of the MNM intervention. Interview questions were administered to the respondents in Tanzania through Skype-enabled -telephone (skype-out calls) by the researcher from the Netherlands. The telephone interviews investigated:

- On-farm management practices such as planting dates, plant spacing, fertiliser types and quantities, as well as application techniques and weeding for the 2019/20 season.
- Whether there was a change in fertiliser use practices as compared to 2018/19, and the achieved yield in the 2019/20 season;
- Farmer perceptions of drivers of change in fertiliser use practices and yields between 2018/19 and the 2019/20 seasons
- The farmer perceived impacts of MNM intervention on yield for the 2019/20 season.

The aim of the interviews was to gain insights into what drives changes in fertiliser use practices and maise grain yield other than the MNM intervention. Table 2 summarises the key variables used during the interviews and the type of data collected, whether qualitative or quantitative. For more details on the questions, farmers were asked during the Skype-telephone enabled interview see the questionnaires used (Appendix 2).

Table 2 Summary of key variables used during telephone farmers' interviews in 2020 after MNM intervention.

A: Quantitative data			
	Variable	Control	Intervention
1	Type of inorganic fertiliser	✓	✓
2	Fertilizer Quantity (kg/ha)	✓	✓
3	Methods of fertiliser application (placement against broadcasting)	✓	✓
4	Timing of fertiliser application at different stages of maise growth (emergence, 5-6 leaves, knee-high, 8-10 leaves, at tasseling and silking)	✓	✓
5	Types of seeds, planting dates and spaces	✓	✓

6	Weeding	✓	✓
7	Harvest (maise grain yield-- t/ha)	✓	✓
8	MNM impact outcomes (Nitrogen use efficiency and yield)	×	✓
	B: Qualitative data		
	Variable	Control	Intervention
1	Why and how change occurred in fertiliser use practices and yield between the seasons	✓	✓
2	MNM usefulness	×	✓
3	Willingness to participate in the second round of MNM intervention in 2020	×	✓
✓ = variable applicable *x =variable not applicable*			

2.5 Data Analysis

Data analyses were performed in the R statistical package. R is a free software programming language for statistical computing in Rstudio (R Core Team, 2020). Rstudio is an integrated development environment for R (RStudio Team, 2020). The packages "tidyverse" and "modelr" were used for tidying of the data and performing the analyses and visualisation (Wickham, 2020; Wickham et al., 2019).

2.5.1 The DD analyses

The DD method was employed to estimate the impact of MNM. This was done through the following steps;

1) Comparison fertiliser use practices and achieved yields between the control and intervention group **before** the MNM intervention (2018/19 season)
2) Comparison of fertiliser use practices and achieved yields between the control and intervention group **after** the MNM intervention (2019/20)
3) Comparison of **a change in** fertiliser use practices and achieved yields **between 2019/20 and 2018/19** for the control and intervention groups.

Second, the DD was employed to estimate the impact of MNM on N-AE of the intervention group based on the formula shown in table 3. Thus, changes in N-AE before and after MNM intervention for the control group were subtracted from Changes in N-AE before and after MNM intervention for the intervention group. As stated in chapter one of this report, farmers with an MNM intervention was expected to have a larger increase in N-AE between the two seasons than farmers without the MNM intervention.

Table 3:The difference-in-difference (DD) method to evaluate the Maize Nutrient Manager (MNM). C_0 and C_1 represent the Control group before and after MNM intervention, respectively. M_0 and M_1 represent the (MNM treatment group before and after the intervention.

	MNM group	Control group	Differences across groups
Baseline (2018/19)	M_0	C_0	M_0 -C_0
Follow-up (2019/20)	M_1	C_1	M_1 - C_1
The Difference in mineral P and N inputs, N-AE & gained yield across time	M_1 -M_0	C_1- C_O	MNM Advice Impact = (M_1 -M_0)-(C_1- C_O)

2.5.2 N-AE analyses

N-AE can be calculated using Equation 1 (Dobberman, 2007) if a field experiment with different treatments is used.

$$\mathrm{N{-}AE}=(\mathrm{Y_F}-\mathrm{Y_C})/\mathrm{F_{appl}} \qquad (1)$$

Where Y_F and Y_C refer to grain yields [kg ha^{-1}] in the treatment where fertiliser N has been applied and in the control plot, respectively, and F_{appl} is the amount of fertiliser N applied [kg N ha^{-1}]. N-AE is also a short term indicator of economic return of fertiliser applied (Fixen et al., 2015)

2.5.3 Significance testing and regression model analyses

In this study, field experiments were not conducted. Therefore, we could not use Equation 1 to calculate N-AE. However, we did have a range of N applications from different farmers (between 0 and 200 kg N applied per ha) with different obtained yields. By plotting the yields versus the N applications, the additional maise yield per kg additional N applied (N-AE) was estimated based on the slope of the regression line, using a linear regression model (Equation 2)

$$Y \sim a + b * N + \varepsilon \qquad (2)$$

Where Y is the maise yield obtained by a farmer, a is the estimated maise yield for a group of farmers without fertiliser N application, b is the estimated N-AE, N is the N applied by a farmer and ε an error term for unexplained variation. In this study, a linear model was run separately for each group of farmers (control and MNM in both seasons) to estimate N-AE. In addition, linear models were also run for a groups combined to test for a significance difference in N-AE between years or groups (Equation 3)

$$Y \sim a + b * N + f_{s,g} + \varepsilon \qquad (3)$$

In which f denotes the year (2018/2019 or 2019/2020) and the farmers group (control or MNM) of a farmer.

To determine the significance in differences between groups before and after the intervention, the t-statistic was used (Field, 2018). For the continuous outcome variables such as fertiliser quantity (kg/ha) and yield (t/ha), independent t-tests and paired-samples t-tests were applied. The independent t-test tested a significant difference in the means of the outcome variables between groups. At the same time, the paired-samples t-test was applied to compare the means of the variables within groups.

For categorical outcome variables such as methods and timing of fertiliser application, chi-square test, fisher's exact test and McNemar's Consistency test were applied. The chi-square test tested for the significant difference of the means between groups before and after the intervention. Since the samples after intervention were small, fisher's exact test was used (Field, 2018). To check the consistency across categorical variables within groups and between season, the McNemar's Consistency test was applied.

Regression analysis was carried out to investigate the relationship between predictor variables (mineral N and P) with an outcome variable such as yield. To test the goodness of fit, regression models were compared using ANOVA in R.

2.5.4 Qualitative data analyses

The theory of planned behaviour (TPB) and the 'rethinking adoption' framework developed by Glover et al. (2019) guides the analysis of the qualitative data collected. The qualitative data collected were part of responses from the telephone interviews (Table 2). Descriptive statistic, the DD analyses and qualitative information in the form of narrative based on farmers responses during the interviews are presented under the "Result" chapter of this report.

3. Results

3.1 Fertiliser use practices and maise yields before MNM intervention (2018/19)

First, fertiliser use practices and obtained yields of the control and MNM groups are compared before the MNM intervention in the 2018/19 season. The fertiliser use practises include; types of basal and top-dressing fertilisers used, the quantities of P and N in the applied fertilisers, methods of basal fertiliser application (placement), and timing of top-dressing fertiliser application. The average maise grain yield is also compared between the groups before the MNM intervention.

3.1.1 Fertiliser use practices: basal fertiliser use at planting, and first top dressing fertiliser application.

Fertiliser types used at planting and at the top-dressing stage were different between the two groups of farmers. The majority (n=260) of farmers of the intervention group (n=307) used P-fertilizers (DAP) at planting and N-fertilizer (Urea) at top-dressing. A significant number of farmers (40) from the control group did not apply any basal fertiliser at planting in the 2018/19 season, compared to only 34 farmers of the intervention group (Figure 3). Further analyses revealed that the majority of these farmers who did not apply fertiliser at planting practised dry planting. Dry planting (sowing maise seeds before the rains) makes farmers apply basal fertiliser such as DAP later, at emergence when there is adequate soil moisture (Figure 3A).

At the time of top-dressing of fertiliser application, Urea was most commonly used by both groups. However, the use of fertiliser P, such as DAP was also observed at the top-dressing stage in both groups. The control group had a relatively higher percentage of farmers using DAP as top-dressing fertiliser (Figure 3A). Twenty-one control group farmers (87.5%) who used DAP as top-dressing, did not apply any fertiliser at planting (Figure 3C).

Hence, control groups farmers more often used no basal fertiliser, practised dry-planting, and used DAP as top-dressing fertiliser, than the intervention group. This suggests that the groups were different in above-mentioned fertiliser use practices in the 2018/19 season (the before intervention).

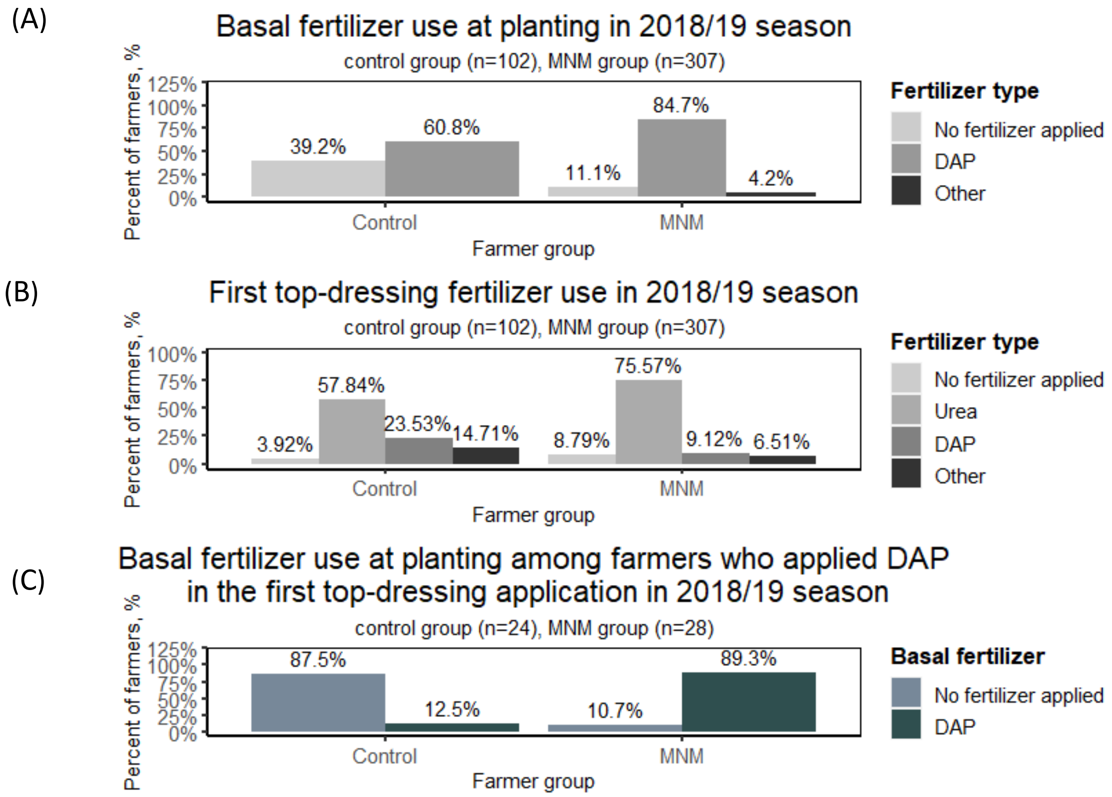


Figure 3: (A) Types of basal fertilisers applied at planting by both the control and Maize Nutrient Manager (MNM) farmer groups in the 2018/19 season before the MNM intervention. (B) Topdressing fertilisers after planting for both groups. (C) Sub-group of control (n=102) and MNM (n=307) who applied DAP as top-dressing fertiliser

**In figure 3A and B* "other" represents fertilises other than DAP and Urea at planting and at first top-dressing application: At planting includes; Yara Mila cereal, Yara Mila cereal OTESHA, NPS and NPSzinc. *At top-dressing include: CAN, SA, Bela-CAN26, and Yara-Vera-Amidas*

3.1.2 Methods of basal fertiliser application and the timing of top dressing fertiliser application

Chi-squared independence tests showed that methods of basal fertiliser application and the timing of the first top-dressing application between the control and MNM-intervention groups were significantly different (P<0.03). More MNM group farmers used fertiliser placement methods (instead of broadcasting) than did the control group farmers (Figure 4A). Also, MNM intervention group farmers seemed to apply first top-dressing fertiliser earlier than the control group farmers.

The timing of first top-dressing fertiliser was more diverse among control group farmers than MNM farmers; Both groups tend to have substantial numbers of late appliers of first top-dressing fertiliser: 41 farmers for control, and 108 for MNM (Figure 4B).

(A)

(B)

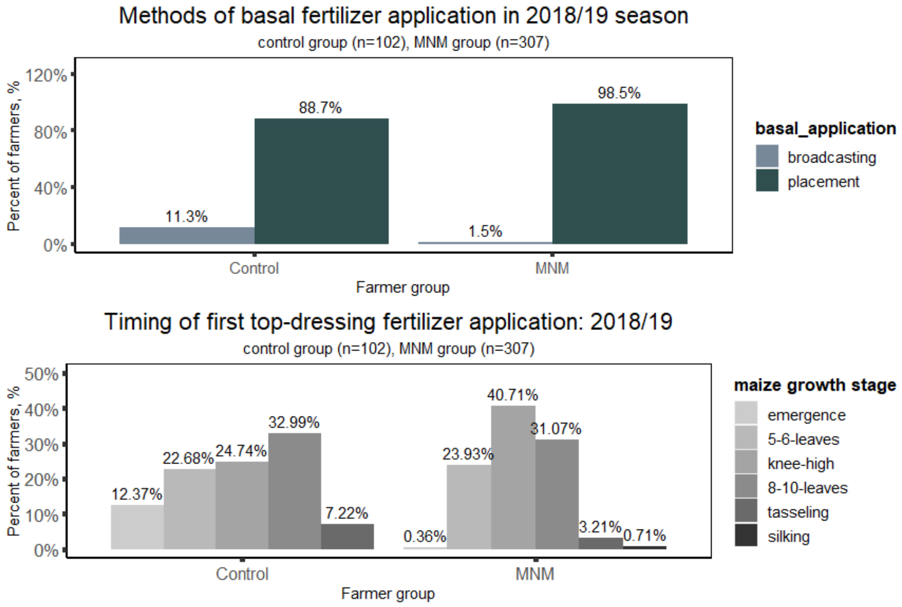


Figure 4: (A)methods adopted by farmers from both the control and Maize Nutrient Manager (MNM) groups in the 2018/19 season. (B) Timing of top dressing fertilisers application after planting for both groups.

**Placement in Figure 3A means; placing fertiliser next to, and below seeds at sowing.*

3.1.3 Average Mineral P, N inputs and average yield before the MNM intervention in 2018/19

Farmers in the control group applied on average 18.7 kg P/ha and 76.1 kg N/ha while in the MNM group, on average 23.4 kg P/ha and 87.5 kg N/ha was applied (Figure 5). The results of an independent sample t-test confirmed that the two groups were significantly different in term of mineral P ($P<0.002$) and N ($P<0.032$) inputs at 95% CI. Thus we can conclude that the intervention group applied more P and N in the 2018/19 season before the MNM intervention.

(A)

(B)

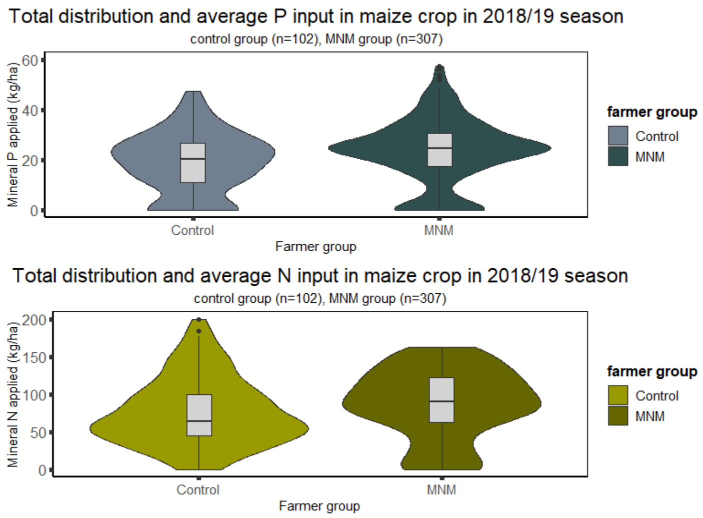
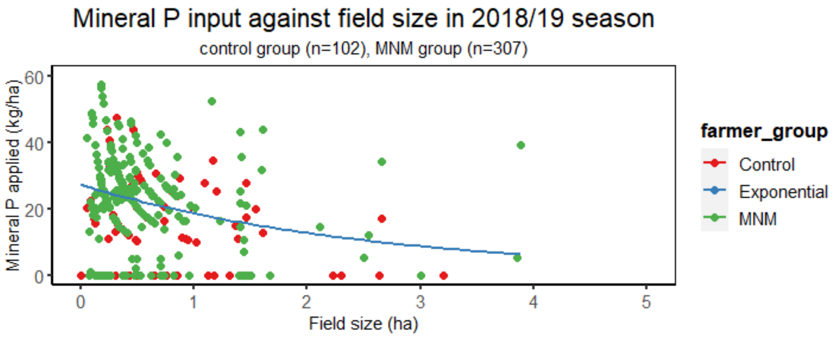


Figure 5: (A) Distribution of mineral P inputs of the control group (mean=18.7kg ha^{-1}) and MNM group (mean=23.4 kg ha^{-1}) from total inorganic fertilisers applied in the 2018/19 season. B) Distribution of mineral N inputs of the control group (mean=76.1kg ha^{-1}) and MNM group (mean=87.5 kg ha^{-1}) from total inorganic fertilisers applied in 2018/19 season.

3.1.4 Change in mineral P and N inputs with a change in maise field size for control and MNM groups

P and N application rates for the control and MNM groups are negatively correlated with field size, with a significant number of farmers in both groups not applying P at all (Figure 6 A, B). Also, the N:P ratio of the applied fertilisers tends to increase with field size, as reported by Andersson et al. (2020). The groups were similar in P and N application rates in relation to maise field size.

(A)



(B)

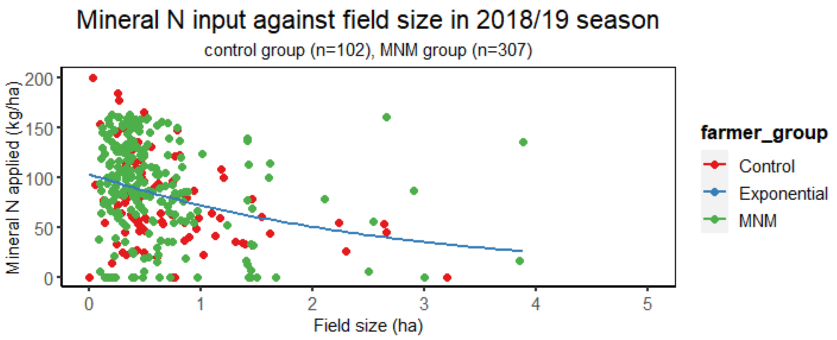


Figure 6: (A) Change in mineral P inputs in relation to maise field size in the 2018/19 season for the control and Maize Nutrient Manager (MNM) groups. (B) Change in mineral N applied by the control and MNM groups in 2018/19 season against maise field size.

3.1.5 Average grain yield difference between the control and intervention groups

An independent sample t-test showed that the mean maise yields of the two groups in the 2018/19 season were not significantly different (CI=95%, P> 0.47) (Figure 7), despite the observed differences in total fertiliser application. Apparently, other management practices such as weeding, planting date, timing and method of fertiliser application and the type of seeds used, override the differences in N and P inputs. Other practices that might have influenced maise yield include crop rotation and intercropping with legumes.

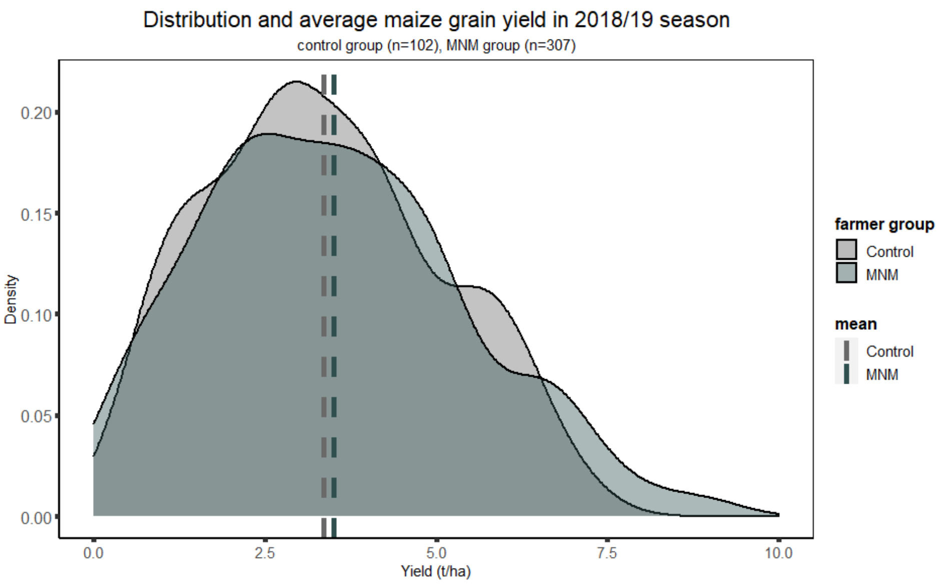


Figure 7: Distribution and average grain yield of the control (mean =3.4 t ha^{-1}) and MNM (mean=3.5 t ha^{-1}) groups in the 2018/19 season.

In summary, fertiliser use practices of the control and MNM intervention groups thus differed significantly with respect to methods of basal applications, the timing of first top dressing fertiliser application and the application rates of P and N. The differences will be discussed further in chapter 4. The next section compares the differences between the control and intervention groups after the MNM interventions, that is, at the end of the 2019/20 maise growing season.

3.2 Fertiliser use practices and maise yields after MNM intervention in (2019/20 season)

This section discusses the differences in fertiliser use practices and yields of the control and MNM groups following the MNM intervention (in the 2019/20 season). After the MNM intervention, the sample size of both the control and MNM groups became smaller, due limitations on doing fieldwork. For the control group, the post-intervention sample is 35 farmers (n=102 before the intervention), while for the MNM group, it is 40 farmers (n=307 before the intervention). The analyses below tracks the changes that occurred among the same sub-samples of 35 control group farmers and 40 MNM intervention group farmers, instead of comparing differently sized groups in time.

3.2.1 Fertiliser use practices: basal fertiliser use at planting, and first top dressing fertiliser application.

As before the intervention (MNM advice provision before the start of the 2019/20 season), more farmers of the control group (13 or 37%) did not use any basal fertiliser at planting as compared to the MNM group farmers (9 or 22.5%) of the (Figure 10A & 11A). Also, more MNM farmers (29 or 72.5%) used DAP as basal fertiliser at planting than did control group farmer (19 or 54.3%; (Figure 10A & 11A).

Also similar to before the intervention, both farmer groups use Urea as their main source of N in top-dressing fertiliser applications. Further analyses showed that all farmers (11 or 31.4%) of the control group who applied DAP after planting (as top-dressing), practised dry-planting (Figure 10B). The delayed DAP application (at emergence rather than at the time of sowing) suggests the same phenomenon of ''dry-planting'' as was noted for the 2018/19 season, and which is common in the area.

The results of Fisher's exact test of independence (P>0.1) revealed that the two groups were not significantly different in their timing of top-dressing fertiliser application in the 2019/20 season. Application of top-dressing fertiliser at knee-high for both groups shows a tendency of late application of first top-dressing fertiliser, even among MNM users (Figure 10C & 11C). Further investigation is needed in the field to find out why farmers prefer knee-high measurement rather than leaf-counting to time their top-dressing applications.

The two groups in the 'after intervention' did not differ much from each other compared to the 'before intervention' with regard to types of fertilisers used, and timing of the first top-dressing fertiliser application.

3.2.3 Change in mineral P and N inputs of the control and intervention groups after MNM intervention

The mean P application rate was 23.4 and 28.5 kg P ha-1 for the control and MNM groups, respectively. The average N application rate was 93.1 kg N ha^{-1} and 97.4 kg N ha^{-1} for the control and MNM groups, respectively (Figure 8). The results of the independent sample t-test at 95% CI revealed that the two groups were not significantly different in mineral P (P>0.07) and N (P>0.73) application rate in 2019/20., where they had been in the 2018/19 season.

(A)

(B)

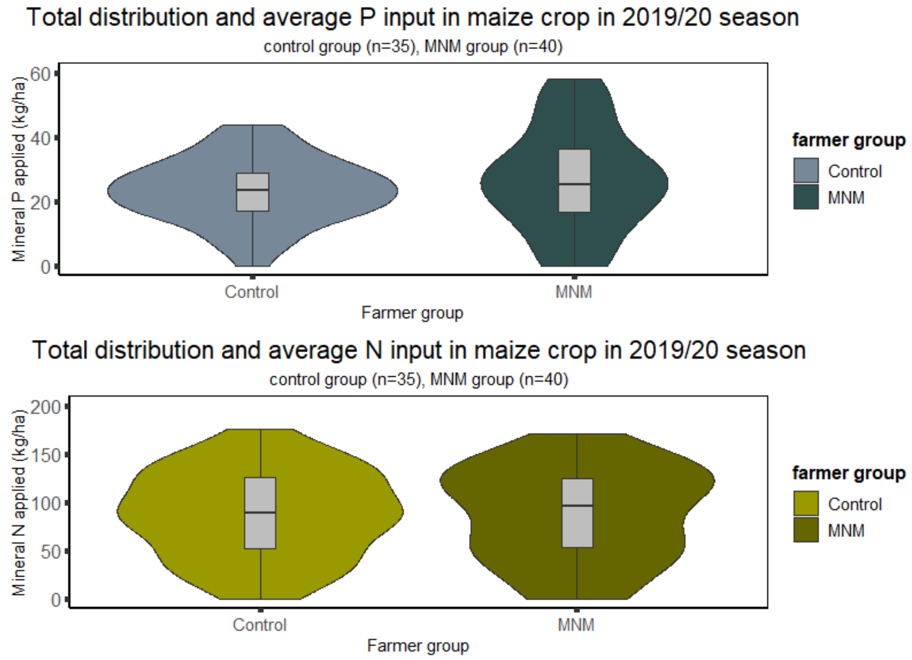


Figure 8: (A) Average mineral P inputs from total inorganic fertilisers applied in 2019/20 season by farmers from both the control and Maize Nutrient Manager (MNM) groups. (B) Average mineral N inputs from total inorganic fertilisers applied in 2019/20 season by farmers from both groups.

3.2.4 Comparing obtained maise grain yield by the control and intervention group after intervention.

The results of an independent t-test found that the mean yields of the two groups were not significantly different (95% CI, P>0.741) in the 2019/20 season. However, the MNM group seemed to have a slightly higher maise yield on average (4.9t ha^{-1}), with a maximum of 15 t/ha (Figure 9). The average yield of the control group was slightly lower (4.7t ha^{-1}) with a maximum of about 10 t/ha(Figure 9). As it was in the before the intervention, the average yields of the two groups are similar in the after the intervention.

Since there were no much differences between groups after the intervention, in the next section, we investigate changes in fertiliser use practices and obtained yields within the groups; before and after MNM intervention.

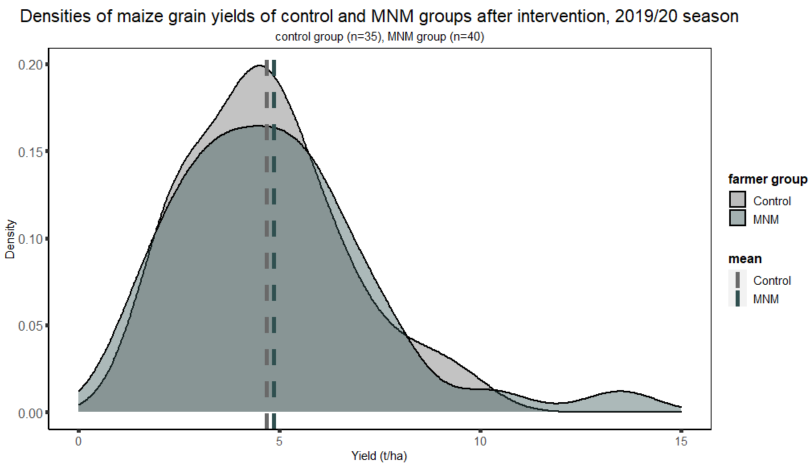


Figure 9:) Average and distribution of maise grain yield of the control and MNM groups in 2019/20 season.

3.3 Changes in fertiliser use practices and yield between the 2018/19 and 2019/20 seasons.

This section investigates changes in fertiliser use practices and yield variation for the control and MNM groups by comparing practices and yield before and after the intervention. Fertiliser use practices and yields of the farmers in sub-samples of n=35 and n=40 in the 2019/20 for control and MNM respectively are compared with same sub-samples in the 'before intervention'.

3.3.1 Changes between seasons in the control group (n=35)

Changes in fertiliser practices of the control group; basal fertiliser use at planting (figure 10A) before and after the intervention. Figure 10B and C shows changes in practices of the first top-dressing fertiliser types and timing of application, respectively.

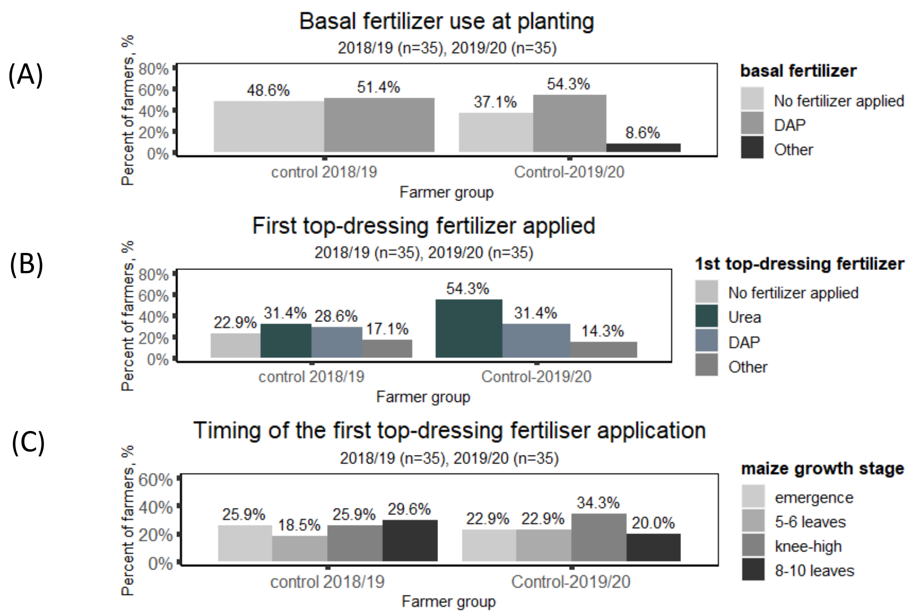


Figure 10:comparing fertiliser use practices of the control subset group (n=35) before (2018/19) and after (2019/20) the MNM intervention. A) Basal fertiliser use at planting in the 2018/19 and 2019/20. (B)First, top-dressing fertilisers applied by the group in 2018/19 and in the 2019/20 season. (C) Timing of top-dressing fertiliser at different stages of the maise growth.

**In Figure 9a "other'' represents: Yara Mila cereal, Yara Mila cereal OTESHA, NPS and NPSzinc fertilisers*

**In Figure 9b ''other'' represents fertilisers at top-dressing which includes; CAN, SA, Bela-CAN26, and Yara-Vera-Amidas*

3.3.2 Changes between seasons in the MNM group.

Relatively more farmers (22.5% of n=40) of the intervention group did not apply any fertiliser at planting in the 2019/20 season, as compared to the previous season (12.5% of n=40) farmers in (Figure 11A). At first top-dressing application, 72.5% (of n=40) used Urea this season, whereas in the previous season, 80% had done so (Figure 11B).

The McNemar's Consistency test (P>0.14) results revealed that the MNM group farmers did not drastically change their timing of top-dressing fertiliser application between the seasons, despite more farmers applying first top-dressing at emergence (Figure 11C). However, figure 11C also shows that in the 2019/20 season, more farmers (45%) applied at 5-6 leaves and no farmers applied late at tasselling and silking.

(A)

(B)

(C)

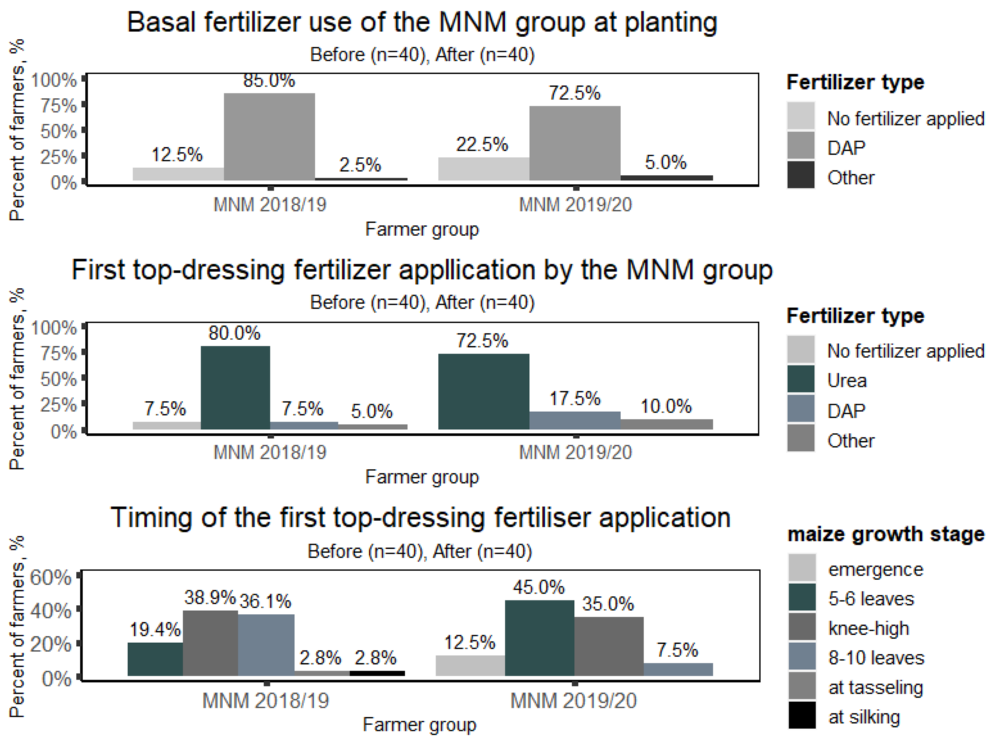


Figure11: A) change in basal fertiliser use of the MNM subset group (n=40) at planting before (2018/19) and after intervention in the 2019/20 season. B)First top dressing fertiliser use of the MNM group before and after the intervention. C) Timing of first top dressing fertiliser application across the season, before (2018/19) and after (2019/20) MNM intervention.

**In Figure 11A "other'' represents: Yara Mila cereal, Yara Mila cereal OTESHA, NPS and NPSzinc fertilisers*

**In Figure 11B ''other'' represents fertilisers at top-dressing which includes; CAN, SA, Bela-CAN26, and Yara-Vera-Amidas*

3.3.3 Changes in mineral P and N input use: control vs intervention groups, before and after MNM intervention

The paired t-test results showed a significant increase of average P (P<0.0001) and N (P<0.0007) input used by the control group in the 2019/20 season over the 2018/19 season (Figure 12A). Among the 35 interviewed control group farmers, 26 farmers applied more P and N in the 2019/20 season compared to the previous season (Figure 13A). On the other hand, the t-test (95% CI) found that there was no significant difference on average mineral P (P>0.5) and N (P>0.14) applied by the MNM group between 2018/19 and 2019/20 seasons (Figure 12b). Figure 12B also shows that about 14 farmers from the MNM group (40) applied less P in the 2019/20, while about 16 applied less N compared to the previous season. 13 and 4 MNM group farmers did not change P and N application rate respectively, between seasons.

To conclude, whereas the MNM group farmers on average did not use more fertiliser in the season following the MNM-intervention, the control group farmers did. However, when individual farmers are compared, 33% of farmers from the MNM group applied more P, and 48% applied more N (Figure 13B).

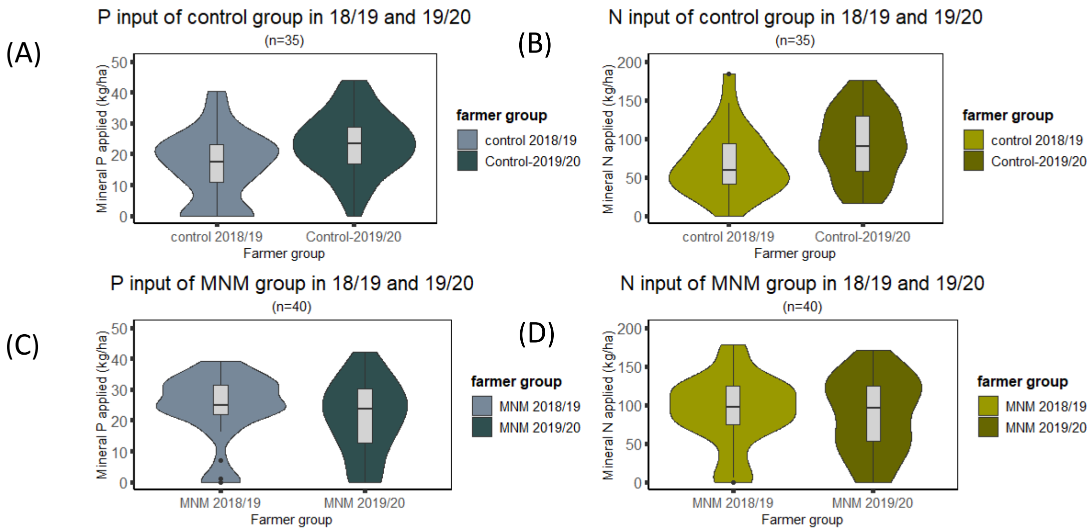


Figure 12: A) Total distribution of P by the control group in 2018/19 (mean=16.1kg/ha) and 2019/20 (mean=25.1kg/ha) B) Distribution of N applied by the control group in 2018/19 (mean=68.5kg/ha) and in 2019/20 (mean=104.1kg/ha). C) Distribution of P applied by MNM group farmers before (mean=26.8kg/ha) and after (mean=23.4kg/ha). D) Distribution of N applied by MNM group farmers before (mean=93.1kg/ha) and after (mean=87.5kg/ha) the MNM intervention.

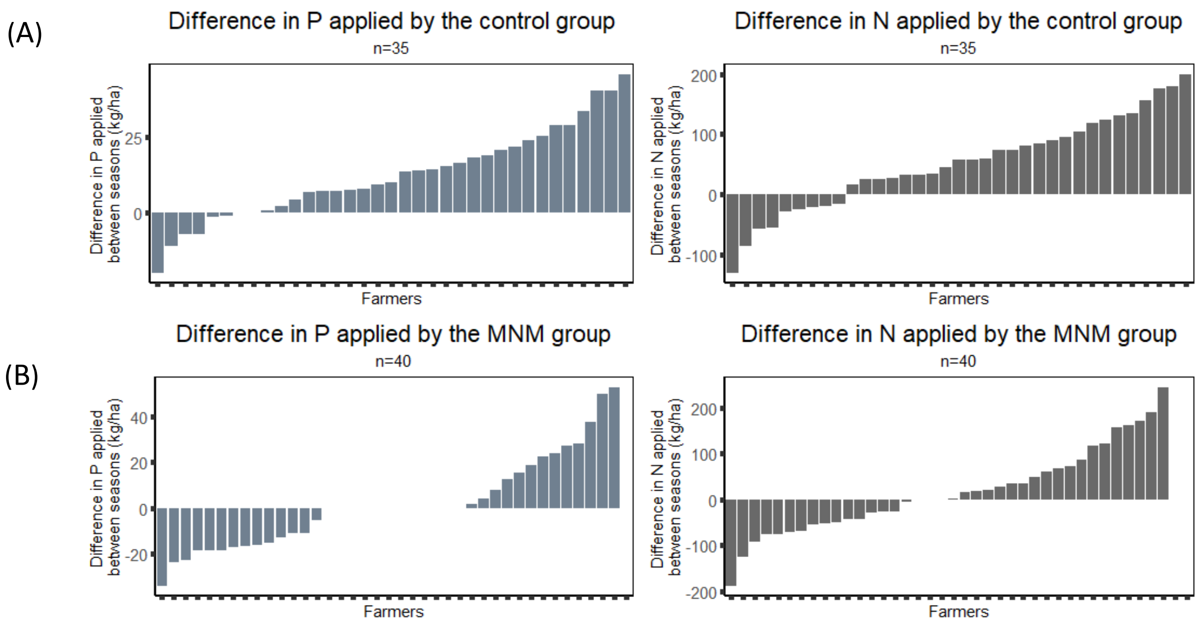


Figure 13: Difference in P and N inputs by individual farmers in control subgroup (n=35) and MNM subgroup (n=40) between the 2018/19 and 2019/20 seasons. (A) The farmers in the control group applied more P and N in the 2019/20 season compared to those in the MNM group. (B) MNM group P and N application rate between the seasons.

3.3.4 Grain yields of control and intervention groups before and after the MNM intervention

Mean maise grain yield of the MNM group increased from 3.7 to 4.9 t ha^{-1} between 2018/2019 and 2019/2020 and that of the control group increased from 3.4 to 4.7t/ha in the 2019/20 (Figure 14). The results of independent sample t-test showed a significant difference ($P<0.01$) in yield of the control group between the seasons. Moreover, a paired t-test results also confirmed a significant difference (95% CI, $P<0.02$) in yield between the seasons for the MNM group.

The DD analyses (based on Table 3), in which we subtract the yield change in the control group from the yield change observed in the MNM intervention groups, shows no yield gain (-0.1t/ha) for the intervention group following the MNM intervention (table 4).

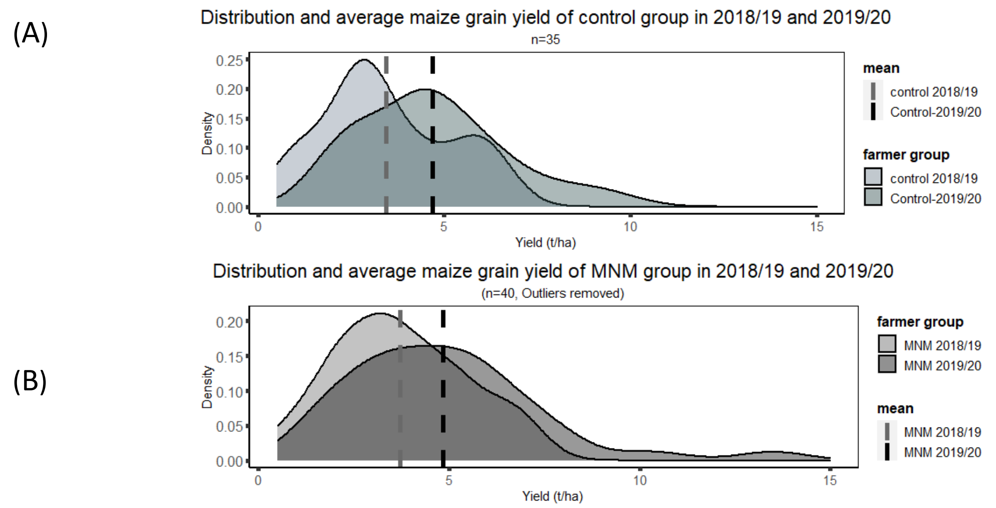


Figure 14: A) Average and distribution of maise grain yields among control group farmers before(2018/19) with a mean of 3.4t ha^{-1} and in 2019/20 with a mean of 4.7 t ha^{-1}. B) Distribution of maise grain yields among MNM group farmers before(2018/19) with a mean of 3.7t ha^{-1} and after (2019/20) MNM intervention with a mean of 4.9 t ha^{-1}.

Table 4: MNM impact on observed gained yield based on difference in difference (DD) econometric method to impact evaluation.

Group	Sample (n=farmers)	Average yield (t/ha)	Season	Difference in yield across seasons (t/ha)
Control	35	3.4	18/19	1.3
	35	4.7	19/20	
MNM	40	3.7	18/19	1.2
	40	4.9	19/20	
The difference in yield across groups → MNM impact on yield =				-0.1

3.4 Agronomic nitrogen use efficiency (N-AE)

The investment-based MNM app is focused on improving the use efficiency of the fertilisers farmers are able to apply. This why this impact evaluation focuses on N-AE. N-AE of the MNM group changed from 8.31 in 2018/19 to 27.39 additional kg grain yield/kg N applied in the 2019/20 season. Meanwhile, the N-AE of the control dropped from 21.0 in 2018/19 to 19.90 additional kg grain yield/kg N applied in 2019/20 season (Figure 15, Table 5).

Using the DD method (Table 3 & 5), the N-AE differences = (27.39 -8.31)-(21.0- 19.9) result in an N-AE gain of 17.98 (95% CI) additional kg grain yield/kg N applied between the two seasons due to MNM advice. Hence, whereas the control group farmers used more fertiliser inputs in the 2019/20 season than in the season before, their fertiliser use did not become more efficient – which was to be expected as they did not receive advice. By contrast, fertiliser use of the intervention group became more efficient following the MNM intervention.

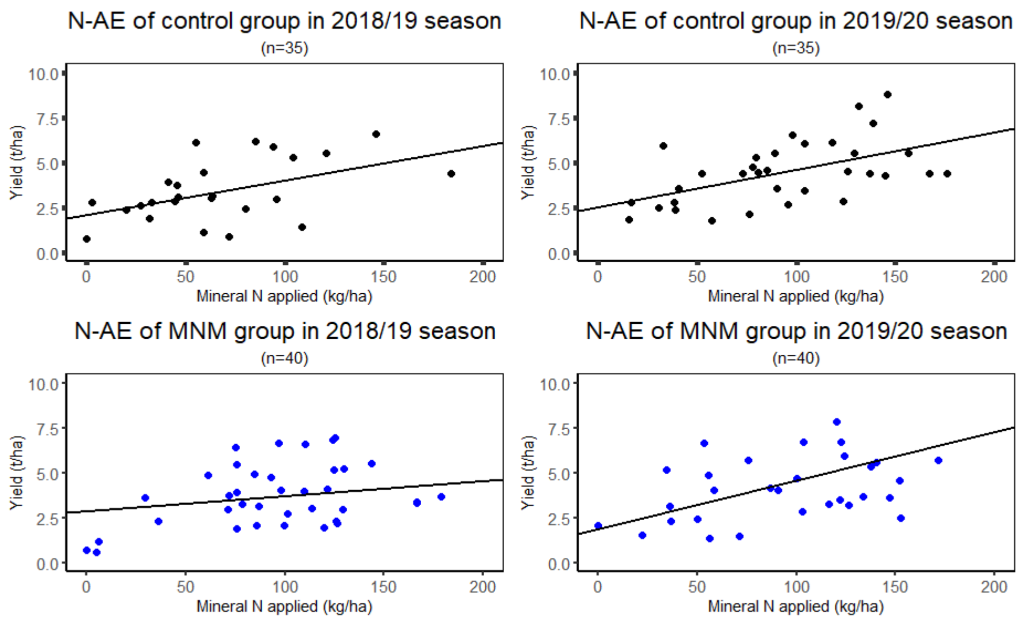


Figure 15: Agronomic N use efficiency of the Control and MNM groups in the 2018/19 and 2019/20 seasons after the MNM intervention.

Table 05: Agronomic Nitrogen use efficiency, N-AE (95% CI) [additional kg grain yield/kg N applied] of the control and MNM groups before (2018/190 and after (2019/20) MNM intervention.

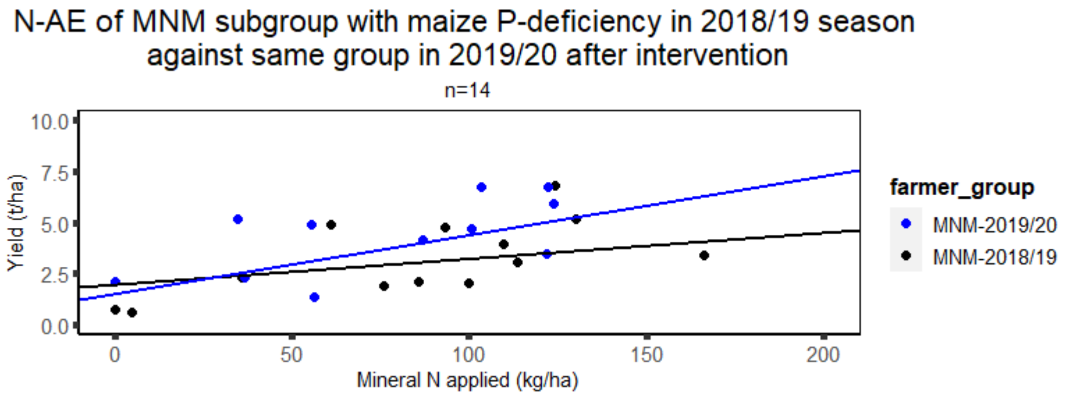
Group	Sample size (farmers)	Average N-AE	SEASON	The difference in N-AE across seasons
Control	35	19.9 +/- 7.36	2018/19	1.1
	35	21.0+/- 7.75	2019/20	
MNM	40	8.31 +/- 4.34	2018/19	19.08
	40	27.39 +/- 3.25	2019/20	
The difference in N-AE across groups → MNM impact on N-AE =				**17.98**

3.4.1 Effect of mineral P on the N-AE of the intervention group farmers who observed maise P-deficiency in 2018/19 season

This sub-section investigates the effect of NP on N-AE, as P can influence the nutrient uptake (Example N) of the maise plant, and consequently affect N-AE (Dobberman, 2007). A subgroup of 14 farmers-observed P-deficiency is studied. In addition, the MNM gives different N:P ratio advices depending on farmers-observed P deficiencies (Figure 17). If farmers observed P -deficiency in their maise in the previous season, they were advised to follow a standard NP of 4:1 (Andersson et al., 2020).

NP ratio had a significant effect ($P<0.03$) on N-AE of the MNM subgroup (n=36) after removing four outliers, with lower NP ratio resulting in higher N-AE (Figure16B). However, comparing the N-AE of the MNM subgroup (n=14) which observed P-deficiency in the 2018/19 season against this season, there was no significant difference (P>0.1) of N-AE in 2019/20 between the seasons (Figure 16A).

(A)



(B)

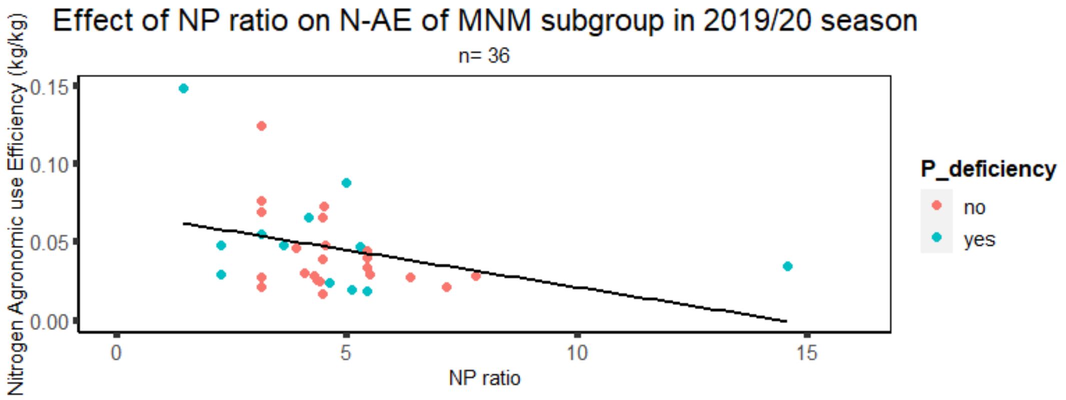


Figure 16: A) Agronomic N use efficiency (N-AE) before and after the MNM intervention for the MNM subgroup, which observed maise P-deficiency in 2018/19. B) Effect of NP ratio on N-AE of the sub-group of farmers who observed maise P-deficiency and non-observers in 2018/19

Figure 16 shows changes in NP ratio of the MNM group (n=40) between season in relation to the advised NP ratios of 6:1 and 4:1. There was a tendency of farmers in 2019/20 season to converge towards the NP ratios advised by MNM (Figure 16B) compared to the previous season. This suggests a desirable trend of balancing N and P application rates as the results of MNM use.

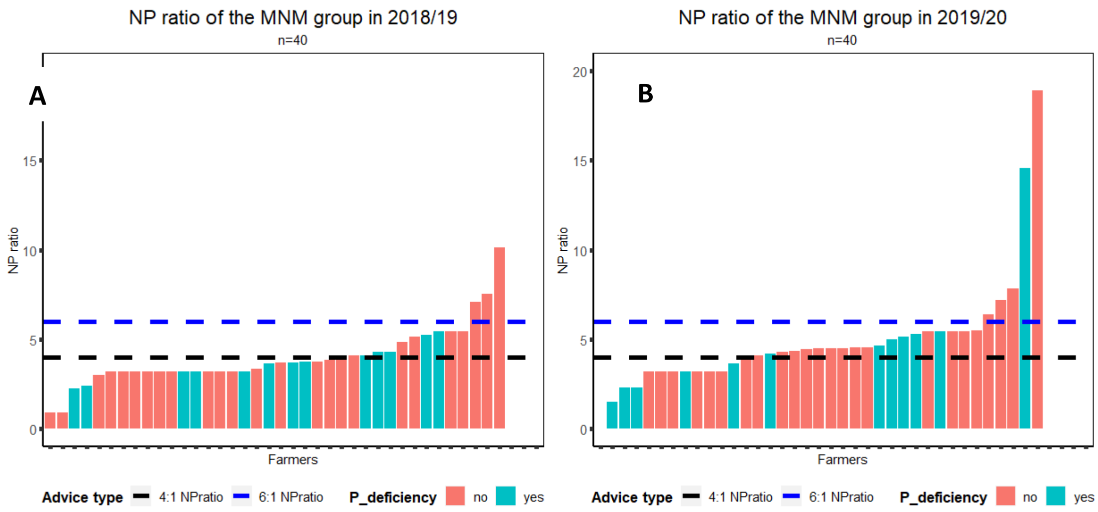


Figure 17: Changes in NP ratios of the MNM subgroup before and after the intervention. A) The bar plot shows two categories of farmers: farmers who observed P-deficiency and non-observers. It also shows the two main MNM advices farmers received. The farmers-observed P deficiency received a 4:1 NP ratio, while the other category of farmers received a 6:1NP ratio. B) The bar plot shows how the two categories of farmers converged towards the MNM advised NP ratios after MNM intervention in the 2019/20 season.

In conclusion, the MNM group did not significantly increase their P and N application rates in the 2019/20 following the MNM intervention, but their NP ratios seemed to improve. Moreover, the N-AE of the MNM group (n=40) also improved significantly (P<0.01), as shown in figure 15. By contrast, P and N application rates of the control group (n=35) increased substantially, while the N-AE did not increase.

3.5 What farmers perceive as drivers of change in fertiliser use practices between the two seasons (2018/19 vs 2019/20)

Farmer interviews (by skype to phone) were used to investigate the how and why of the observed differences in fertiliser use practices between the seasons. In this subsection, qualitative information collected during the farmer interviews is presented. Farmers' perceptions of factors that drive change in fertiliser use practices and achieved yields offered insights into how and why the observed changes occurred.

3.5.1 Why observed difference in fertiliser use (type, quantity, timing and method of application) between the two seasons (MNM and control)

First, farmers were asked about the factors that explain differences in fertiliser use between the two seasons. Types of basal and top-dressing fertilisers did not change; Farmers from both control and MNM groups used mainly DAP and Urea (Figure 7a &b).

The quantity of fertiliser P and N: farmers from both groups reported two main cases(i.e. more or less P and N inputs in 2019/20 season) with regard to changes in fertiliser P and N inputs between the two seasons;

Case 1, (Used more fertiliser P and N): About 26% (9 out of 35) of the interviewed farmers from the control and 8% (3 out of 40) from MNM groups, reported having used more fertiliser P and N in 2019/20 season. Their reports are in line with comparative analysis of P and N use between the seasons, which showed a significant increase in P and N in 2019/20 season (Figure 12). The interviewed farmers (n=75) provided the following reasons for the increase in fertiliser use:

- *Change in income:* 11% of the interviewed farmers reported that increase in fertiliser use was due to having more cash this season;
- *Floods* forced farmers to use more fertilisers this season as fertiliser N was carried away by the flood after application (3% of the interviewed farmers reported this)

Case 2 (Used less fertiliser P and N): About 23% (8 out of 35) of interviewed farmers from the control group and 20% (8 out of 40) from the MNM group reported to have used less P and N in the 2019/20 season. On the other hand, the t-test (95% CI) found that there was no significant difference_on average mineral P (P>0.5) and N (P>0.14) applied by the MNM group between 2018/19 and 2019/20 seasons (Figure 12B &C).' The reasons given for the low use of P and N were:

- *Judicious use of fertiliser as a result of MNM advice:* 35% (14 out 40) of interviewed MNM farmers reported that MNM tool helped them to know the exact size of their maise field, and the exact amount of P and N to spend. However, to check if this is true, more analyses comparing the amount advised against the actual (DAP and Urea) use need to be done.
- *Change in income:* 8% (6 out 75) of interviewed farmers said they were unable to buy adequate fertiliser for their maise fields due to lack of cash.
- *Floods* interrupted fertiliser application calendar which resulted in low input of P and N (only 7% of interviewed farmers reported this)

In summary, the observed change in P and N application rates by the control and MNM groups were mainly caused by the change in income and rainfall variability between seasons.

Timing of top-dressing fertilisers and methods of basal application: Farmers reported that untimely application of top-dressing fertilisers was due to flood, and a shortage of cash (Figure 10). All of the interviewed farmers from the control and MNM groups used placement methods at basal and top-dressing application.

3.5.2. What caused yield variation between the two seasons? (2018/19/vs 2019/20)

During farmer interviews, 29% (10 out 35) of farmers from the control and 40% (16 out 40) from the MNM group reported higher maise yields in the 2019/20 season than in the 2018/19 season. Yield analyses results also showed a significant increase within both groups (Figure 14), which confirms what farmers reported. Farmers (n=75) from both groups gave the following main reasons for the reported yield increases:

- *Better use of fertiliser P and N this season* (reported by 40% of farmers)
- *Use of better seeds:* 92% of farmers used hybrid seeds compared to 89% of the same group using hybrid in the previous season.

On the other hand, some farmers, 60% from control and 20% from the MNM group, reported lower yields in the 2019/20 season. This finding may appear to contrast the results of the yield analyses (Figure 14) that showed a significant increase from 2018/19 to 2019/20 within both groups. However, when viewed from an individual farmer perspective, the low yields are likely to be true, for the following reasons, as reported by farmers:

- *Floods:* 35% (26 out of 75) of the interviewed farmers reported a lower yield this year due to flood (rotting of maise cobs at delayed harvest, delayed weeding, loss of fertiliser due to flooding);
- *Poor fertiliser use.* Reported by 13% (10 out 75) of interviewed farmers;
- *Use of poor seeds.* Reported by 5% (4 out 75) of interviewed farmers.

3.5.3.Farmers' perceptions on the usefulness of the MNM app (MNM group only)

At the end of the phone interviews, intervention farmers were asked about the MNM application. Fifty-eight per cent (23 out of 40) of the interviewed MNM intervention group farmers commented that the MNM tool was useful because:

- It enabled better planning of fertiliser use at the beginning of the season (recommended type and balanced quantity of P and N fertiliser) based on an accurate maise field measurement by the MNM tool.
- It enabled evaluation at the end of the season by comparing investment (fertilisers and seeds) against maise grain yield (output).

Further, 80% (32 out 40) of the interviewed MNM farmers indicated a willingness to be visited again next season and provided with an MNM advice for their maise.

In the next chapter, the results of this study are substantiated further. The major findings in relation to the objectives of the study are discussed and compared to the findings of other similar researches. Also, the implications of the findings are pointed out, and recommendations are provided for further researches.

4.Discussion

This study investigated the agronomic impact of MNM fertiliser advice on fertiliser use efficiency (FUE) and maise grain yield among MNM users in Tanzania. The study found that there was a significant impact on the use of MNM advice on the N-AE, the used indicator for FUE.

Two subgroups of farmers (35 control, 40 MNM) were investigated to study the changes in N-AE between the 'before and after intervention'. However, the N-AE analyses found that the MNM subgroup was not representative of the larger MNM group (n=307). Regarding fertiliser N and P application rates, the control group appeared to have increased its fertiliser use in the season following the researchers' visit, unlike the MNM group. We discuss a bit more about the differences in N-AE and the change in fertiliser application of the two groups between seasons and its implications in the subsections that follow.

The study also found that there were no effects of MNM on fertiliser management practices that could be observed in the reported data except for the timing of top-dressing fertiliser application and the balanced application of fertiliser N and P. The timing of top-dressing fertiliser application of the intervention group seems to improve in the 2019/20 season (Figure 11) following the MNM intervention. The balanced NP application rate was assessed based on the N:P ratio advice. Figure 16B suggests farmers were converging towards a 6:1 NP ratio advice in the 2019/20 season. Moreover, interviews with farmers revealed that the observed changes in fertiliser use practices and yield are not only the result of MNM-advice, as an increase in N-AE suggests. Farmers from both the control and the MNM group offered insights into drivers other than MNM that caused the change in fertiliser use practices and yield. Below, the implications of the findings are discussed in more detail.

4.1 Field-specific advice for better fertiliser use efficiency in smallholder maise farming

The econometric approach to impact evaluation used suggests that the MNM had a positive impact on the economic return from using inorganic fertilisers. This was shown by the increase in agronomic nitrogen use efficiency (N-AE) following the MNM intervention.

This showed that fertiliser management advice tailored to field-specific conditions and the field's management history could contribute to improved nutrient use efficiency. Deichmann et al. (2016) also found that better, field-specific advice, delivered through extension services, is likely to make crop production efficient. However, using N-AE as a proxy for FUE has its limitations (Dobberman, 2007). Comparison between the season does not take account of (unevenly distributed) residual effects of earlier fertiliser use. As a consequence, the N-AE value of the second season might have caused an underestimation as the residual effects of fertiliser occur later (Fixen et al. 2015). However, there are also residual effects of fertiliser use before MNM was used, which will have influenced N-AE in the first season. Single season assessments of N-AE, therefore, have limited value. One needs to follow the development of N-AE over several seasons to analyse trends.

To overcome the limitations of this study's N-AE assessments requires a multi-year approach, and an estimation of the long term contribution of the fertiliser applied to crop yield (Fixen et al. 2015). This observation has implications for the future design of MNM and similar tools; valid evaluation of such tools requires several seasons of data. Moreover, to provide more concrete evidence for improved FUE following MNM use in the future, indices other than N-AE for measuring FUE can be explored. For example, Partial Factor Productivity of applied Nitrogen (PFP N). Ladha et al. (2005) define PFP as an index of total economic outputs relative to the use of all N sources (indigenous soil N and applied fertiliser N). PFP N is important for farmers because it integrates use efficiency of both soil and applied nutrients like N (Dobberman, 2005). With PFP, the residual effects of fertiliser application can be captured. However, PFP requires field experiment and soil analyses which were beyond the scope of this study.

4.2 Fertiliser management practices and attained grain yield

The 4R principles of nutrient (NPK) stewardship (nutrient stewardship, 2020) were at the core of MNM fertiliser advice design with 'right rate' being replaced by '**right nutrient balance'** of N:P (Andersson et al. 2020). The findings of this study showed that fertiliser management practices following MNM use did not change much with regards to fertiliser types used, and methods of fertiliser application. Majority of farmers opted for placement methods for fertiliser application over broadcasting. Farmers perceived placement methods to be better than broadcasting because it allows spot application of fertiliser which is way more economical and effective. Spot application which is placing fertiliser in the hole at planting or next to the plant after emergence is also supported by ICRISAT (2020) and Tabo et al. (2007) for fertiliser use efficiency in SSA. Farmers mainly used DAP and Urea as sources of N and P. Farmers reported that DAP and Urea were the most readily available and least expensive sources of P and N compared to other fertilisers. The report by Andersson et al. (2020) also found that DAP and UREA were the most cost-effective sources of N and P in the Southern Highlands of Tanzania.

4.2.1 Timing of top-dressing fertiliser application

The intervention group showed better timing practices of top-dressing fertiliser N application, as most of its farmers applied between germination and leaf growth stages of maise growth. The demand for Nitrogen is at highest at these two stages, which suggest an active vegetative growth with high N uptake (Wallace et al.,. 2000). Therefore, it was more likely that the better timing of fertiliser N application by the MNM farmer group contributed to the observed increase in N-AE due to MNM.

This has an implication on the future design of MNM. Thus rather than focusing on all aspects of 4R stewardship, it may focus on the key-practices like the timing of top-dressing fertilisers, which may have a substantial effect on FUE and consequently grain yield (Wallace et al., 2000).

Further investigation to understand the 'logic' underlying common fertiliser N management practices in smallholder farming of SSA is important for successful interventions. For example, this study showed that the majority of farmers preferred "knee-high" indicator (Figure 10&11) for timing top dressing fertiliser application to leaf counting, which the MNM advises. As the timing of top-dressing fertiliser application is crucial to improving FUE by matching the supply of N to the demand of the crop (Kirda et al., 2001), more about the common fertiliser management practices by farmers need to be known

Other aspects of nutrient management that might have contributed to the increased N-AE but were not investigated in this study may include; manure use and planting density. Nyamangara et al. (2003) showed that a combination of manure and fertiliser N application could improve crop uptake efficiency of mineral N fertiliser. The crop uptake efficiency can in turn improve N-AE (Dobberman, 2005). Also, optimum planting density can directly influence N-AE as well (Huang, et al.,2017). Other factors that may influence N-AE is the initial soil fertility conditions before the intervention (Vanlauwe et al., 2011). Soil analyses were beyond the scope of this study, as MNM does not incorporate soil field sampling testing.

4.2.2 Dry-planting and timing of fertiliser P application

A substantial number of farmers from the **control group** never applied any basal fertiliser at planting due to ''dry planting''. Dry planting (sowing maise seeds before the rains) is a phenomenon observed in the study area of Mbozi and Momba districts (Kilakila, 2020). ''Dry planting'' forces farmers to apply basal fertiliser at emergence, when there is adequate soil moisture. Dry planting can be a key entry point to better understand farmers' behaviour with regard to fertiliser P use for the MNM to generate proper advice on the timing of fertiliser P application. Since the MNM focuses on the right balanced application of N and P more knowledge on P fertilisation in the study areas is crucial for MNM future design.

4.2.3 Phosphorus (P) deficiency in maise crop production

P is one of the important limiting nutrients to crop production in SSA (Nziguheba et al. 2016). A study in Kenya showed that removing P in fertiliser NPK treatment reduced yield by 50% compared to 43% yield reduction following N removal (Kihara et al. 2013). This study has shown that farmers tend to use too little P fertilisers. A study by Benson et al. (2012) also found that a share of P fertilisers of the total amount of fertiliser applied was less than 30% in SSA. The low use of fertiliser P in SSA, especially in the regions of high potential for crop production has led to P deficiency problem. (E.g. Southern Highlands of Tanzania) (Nziguheba et al.,. 2016).

In this study, P-deficiency in maise was observed by 14 farmers of the MNM group (n=40) in the 2018/19 growing season. With observed P deficiency, the MNM app advised those farmers to lower the N:P ratio to 4:1 in the 2019/20 season. The study found that by the end of the season following the MNM intervention advised farmers did not significantly change their NP application rate according to the advice (Figure 17). However, the overall change in N:P ratio did have significant effects on N-AE of the intervention group (Figure 16). The meta-analysis study by Ichami et al. (2019) on N-AE in smallholder maise farming in Kenya also found a significant effect of applied P on the relationship between N application and N-AE. This implied that MNM could be a useful tool for addressing P deficiency if maise growth history is well recorded.

4.2.4 Was yield gain attributable to MNM use?

MNM users – with less fertiliser application - reached the same maise grain yield on average as the control group with an average increase of about 1t/ha. In the control group, the increased yield was associated with increased fertiliser P and N application rates in the 2019/20 season. Our understanding of why the increase in P and N application occurred only in the control group is limited at the moment. There could have been an 'interviewer effect'; farmers being stimulated to invest more in fertilisers for maise after an extensive discussion with the researcher and measurement of their maise field. The MNM group farmers on average maintained the same N and P input rates although with a lowered N:P ratio. Yet both groups attained the same grain yield on average. For the MNM group, the increase in yield is the result of improved FUE. Thus increased yield gain per unit of fertiliser N uptake (the physiological efficiency) (Dobberman, 2007).

To avoid incorrect conclusions on the impact of MNM, farmer interviews were used to generate insights on the reality in which the MNM intervention operated. Those insights provided an answer to the question of 'how and why' changes in fertiliser use practices and yield occurred. The understanding of how changes occurred is crucial for future design and implementation of MNM and other similar interventions in the maise smallholder farming sector of the Southern Highlands of Tanzania.

4.3 Unforeseen consequences of MNM use.

The rethinking Adoption Framework by Glover et al. (2019) stresses the importance of investigating the unanticipated effects of an intervention. Unintended consequences may emerge during the implementation stage of an intervention.

In this study, farmers reported that the MNM tool helped them to plan for the judicious application and investment of fertilisers at the beginning of the season. The MNM tool incorporates GPS services in its design, helping farmers to measure their maise fields more accurately. With an accurate measurement of farmers' fields, farmers were able to buy the right mix of different fertilisers.

In the next round of MNM implementation, timely provision of MNM advice is important for its success during the season. It was evident during farmers' interviews that farmers would prefer to have MNM advice immediately after harvest when farmers start to plan for the next season. Since record-keeping of farm management was not so common among farmers (Kilakila, 2020), MNM proved to be a useful tool for management record of a scarce resource like fertilisers. A more effective system record can be embedded in the future design of the MNM. As currently, paper-based tools (Appendix 3) as part of MNM are used by farmers to keep their farm management records. Paper-based tools proved to be unreliable during the MNM intervention, as some of them were easily lost, destroyed and sometimes filled with wrong information.

4.4 Limitation of the study

The study was not without its limitations. Travel restrictions to the study area due to the COVID-19 pandemic reduced the sample size and hampered the collection of good quality data from the field. Telephone interviews instead of field visits were conducted to collect endline data for the study. With the telephone interviews, we were only able to reach about 34% of farmers from the control group and 13% of the MNM intervention group farmers who had grown maise in two consecutive seasons. In addition, the 13% group appeared to be not very representative for the total intervention group – as their initial N-AE (8.31 kg grain/kg N) was much lower than the whole MNM-group ((24.31 kg grain/kg N) - which might have led to overestimation or underestimation of the MNM impact. This implies that the selection of samples must be carefully done before and after the intervention to avoid unnecessary bias during impact evaluation (White, 2011).

4.4.1 Drawbacks of the methodological approach

In 2018/19, the control and intervention groups differed substantially in terms of fertiliser use practices. On average, the intervention group had already adopted better fertiliser use practices before MNM was introduced. For example, comparing the two, there was a significant difference in methods of fertiliser application. Majority of farmers from MNM chose placement methods over broadcasting. Also, a significant number of farmers from the control group did not apply any basal fertiliser at planting compared to the intervention group (Figure 3).

The difference between the two groups may be the results of 'selection bias' as farmers did not so much select themselves, but were selected by the extension workers. Selection bias occurs when the selected beneficiaries of the intervention are not a random sample of the population (White 2006). Extension workers tended to select 'better' farmers (who applied more fertiliser and applied fertilisers earlier) compared to the control group. Most often resource endowered farmers seem to benefit more from introduced technology than poor farmers (Chambers & Jiggins, 1987).

To avoid the selection bias in the next round of MNM intervention, farmers should be selected randomly. Extension workers must be aware that MNM intervention can undesirably lead to 'digital divide' if equal chances are not created for both poor resource and better off farmer to participate in the intervention. The digital divide is the tendency of technology use benefitting only a certain group of farmers based on their gender, wealth or digital skills (FAO, 2020).

In 2019/20 the two groups, control and intervention groups were not significantly different in their timing of top-dressing fertiliser, while in the 2018-19 season the MNM group had better practices. The improved practices and higher fertiliser use of the control group are more likely associated with the ''encounter'' between the author (agronomists) and farmers during the survey in 2019 (the interviewer effect). The interviewer effect can have a substantial effect on the social behaviour of the study sample where respondents are more likely to be impressed by the attitude and the knowledge of the interviewer (Davis et al. 2010). During the survey, control group farmers were given advice by the author on how to improve their practices if they had poor practices in the previous season (Kilakila, 2020).

Other limitations of the study are associated with the collection of data on key outcome variables, namely reported maise field sizes, fertiliser inputs and grain harvests. The validity of the MNM advices and impact depends on accurate reporting on fertiliser inputs and yield estimates, and these being based on the same measured maise fields before and after the intervention. Fields visits were planned during harvest time in the study area in order to confirm the maise fields size and yield. However, due the COVID-19 pandemic field visits were not done. Instead, telephone farmers' interviews were carried out. During interviews, to check whether field size was the same, bigger or small maise fields than the original measured maise fields were excluded from the data. Also, inaccurately reported yield was excluded as well.

5.Conclusion

This study has shown that MNM advice had a positive impact on FUE, meaning that with more efficient use of Nitrogen inputs, farmers had higher economic returns from fertilisers used. Such a result suggests that the MNM tool may be useful in providing field-specific advice to improve FUE. However, using N-AE as a measure of MNM impact on FUE, one needs to follow the development of N-AE over several seasons to analyse trends and attribute the changes to the MNM. Timing of top-dressing fertiliser application and the balanced rate of N and P application was found to be key practices to improving the efficiency with which fertiliser N is utilised. Further research may identify more management practices in the area that can improve field-specific fertiliser advisory. Moreover, this study's findings also showed that better-tailored fertiliser advice depends on a better understanding of the farmer's farming reality. Change in farmers' income, and rainfall variability over seasons as reported by farmers during the interview are also key aspects to consider for the design of interventions similar to MNM.

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Appendix 2: Farmers interviews' questionnaires

35 farmers out of 102 farmers from the original control group were fully interviewed. Similarly, 40 farmers out of 307 farmers from the MNM intervention group were fully interviewed, making a total of 75 interviewed farmers in the 'after MNM intervention'. The telephone interviews were conducted via Skype-out calls with selected farmers in the study areas. The telephone interviews were done by the researcher residing in the Netherlands at the time of interviews. During the interviews, farmers' responses were directly entered into an already prepared Excel sheet. Below here are the interview questionnaires for both control and MNM groups.

Telephone interview for the control group

Protocol for the interview

Opening remarks

Researcher's introduction:

Who am I and why calling? And the name of the extension worker responsible for the area.

Interviewees' information:

Name/ID_________

Village and district________

*Ask for the consent

Opening questions:

1. Have you cultivated maise on the measured field area in the season of 2019/20 seasons?
2. Have you received any fertiliser advice between 2018/19 and 2019/20 seasons? →the selected farmer should not have received any advice between the mentioned period

Remind him/her of the information he provided last season (2018/19) about their maise fields:

1. The field is chosen during the survey in 2019
2. whether fertiliser was used or not
3. if he used fertiliser what type and quantity (number & kg of bags):
   i) at basal
   ii) at top-dressing
4. Harvest.

Closed Questions for the season of 2019/20: key variables.

A: questions on inorganic fertiliser use:

1. Crosscheck if you and the farmer are discussing the same maise field as in the previous season.

2. Types of maise seeds used this season, in that particular maise field
3. Planting density
4. Whether fertiliser was used or not in the same field as the previous season
5. If fertiliser was used, what types and quantities (number & kg of bags):
   i) at basal
   ii) at top-dressing
6. Methods of fertiliser application (basal and top-dressing)
7. Timing of top-dressing fertiliser application.
8. Split application of N- fertiliser
9. Weeding method and frequency

B: Harvest: How many “gunia" from your maise did you get this season?
**Gunia ~ 110 kg bag of grain maise*

Topic/ open questions:

1. Why change or no change in fertiliser practices and yield between 2018/19 and 2019/20 season?
2. Fertiliser availability and other unanticipated challenges that have occurred over the season?
3. Climate

Closing remarks:

Telephone interview for the intervention group

Opening remarks

Researcher’s introduction:

-Who am I and why calling? And name the extension worker responsible for the area.

Interviewees’ information:

-Name/ID _________

-Village and district__________

*Ask for the consent

Remind him/her of the information he/she provided for the season of 2018/19

1. Field chosen during the MNM advice provision in 2019.
2. Whether fertiliser was used or not
3. If fertiliser was used what type and quantity (number & kg of bags):
   i) at basal
   ii) at top-dressing
4. Harvest

Closed Questions for this season (2019/20)

1. Check if field chosen and measured during MNM advice provision in 2019 is still same.
2. Maise seed type used this season
3. Planting density
4. whether fertiliser was used or not
5. if he used fertiliser what type and quantity (number & kg of bags):
   i) at basal
   ii) at top-dressing
6. Methods of fertiliser application (basal and top-dressing)
7. Timing of top-dressing fertiliser application
8. Splitting of N -fertiliser
9. Weeding method and frequency.

B: Harvest: How many “gunia" from your maise did you get this season?

******Gunia ~ 110 kg bag of grain maise***

Topic/ open questions:

1. How did you understand the MNM advice and was it easy to follow over the season?
2. Were you able to record everything on the record sheet during the season? If not, why?
3. Did you receive any other advice from other people, E.g. NGOs, agro-dealers that you think somehow contradicted with the MNM advice?
4. Why change or no change in fertiliser practices between 2018/19 and 2019/20 season?
5. Fertiliser availability and other unanticipated challenges that have occurred over the season.
6. Do you think MNM advice was useful to you?

Closing remarks:

Would you like to be visited again by MNM experts and extension worker at the beginning of the next season of 2020/21?